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MEETING THE CHALLENGE OF INSTALLING CANES DURING NEW SHIP CONSTRUCTION ON LPD 28

by

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March 2015

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The budget to build ships and modernize and sustain the C4I systems installed is limited. Lead times for contracting are long, while technology changes rapidly after contract award. The shipboard C4I network examined in this thesis typifies this dichotomy. The challenge is to provide the latest shipboard network that meets the C4I capability needs of the warfighter at ship delivery, while at the same time supporting the shipbuilder's need for Government Furnished Information (GFI) and Government Furnished Equipment (GFE) supporting the Ship Construction schedule.

This thesis analyzed whether to install the legacy Shipboard Wide Area Network (SWAN), where the GFI is firm, or install the newer Consolidated Afloat Network Enterprise System (CANES), where the GFI is evolving, on LPD 28 during New Ship Construction. Recommendations include implementation of the Design Budget Approach during New Ship Construction, use of the Systems Engineering (SE) V Method during C4I network system development to verify and validate warfighter requirements can be met, and a commitment to the GFE Program of Record (POR) C4I network solutions.

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MEETING THE CHALLENGE OF INSTALLING CANES DURING NEW SHIP CONSTRUCTION ON LPD 28

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The budget to build ships and modernize and sustain the C4I systems installed is limited. Lead times for contracting are long, while technology changes rapidly after contract award. The shipboard C4I network examined in this thesis typifies this dichotomy. The challenge is to provide the latest shipboard network that meets the C4I capability needs of the warfighter at ship delivery, while at the same time supporting the shipbuilder's need for Government Furnished Information (GFI) and Government Furnished Equipment (GFE) supporting the Ship Construction schedule.

This thesis analyzes whether to install the legacy Shipboard Wide Area Network (SWAN), where the GFI is firm, or install the newer Consolidated Afloat Network Enterprise System (CANES), where the GFI is evolving, on LPD 28 during New Ship Construction. Recommendations include implementation of the Design Budget Approach during New Ship Construction, use of the Systems Engineering (SE) V Method during C4I network system development to verify and validate warfighter requirements can be met, and a commitment to the GFE Program of Record (POR) C4I network solutions.

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EXECUTIVE SUMMARY

The Shipboard Wide Area Network (SWAN) has been installed on the first 10 ships of the LPD 17 Class and is currently being installed on LPD 27. However, with the recent decision by Congress to authorize funding for LPD 28, the Navy has the opportunity to implement the LPD 17 SWAN Sustainment study recommendation to federate the SWAN network and install the Consolidated Afloat Network Enterprise System (CANES), as opposed to SWAN during New Ship Construction on LPD 28.

Ship delivery, which is a shipbuilding term synonymous with commissioning, for LPD 28 is currently planned for May 2022. Since it typically takes about seven years from contract award to commissioning for a ship of the LPD 17 Class, the Request for Proposal (RFP) package, which must include detailed design information, which the shipbuilder will review and bid on in support of contract award, is expected to be released to industry no later than (NLT) October 2015.

Since an LPD 17 Class CANES design is not mature at this time, providing firm GFI to the shipbuilder in support of the RFP package release creates a dilemma for the Department of the Navy. The dilemma is whether to provide the older, mature design information associated with the SWAN, for which the shipbuilder has experience with installing vs. allowing flexibility for the CANES design to evolve so that LPD 28 will deliver to the Navy a current C4I network in 2022. As CANES will go through at least one hardware refresh cycle between 2017 and 2022, the importance of implementing a flexible design approach is crucial to avoid information technology obsolescence issues at ship delivery. This is situation represents a challenge that the Department of the Navy has faced with New Ship Construction for years, as systems' complexity and technology has advanced this question arises: What is the best way to meet the shipbuilder requirements for early GFI, while at the same time allowing for advanced information technology to continue to mature so that the ship, when completed and delivered to the Navy, will have the latest technology installed?

This research addresses this question and provides a series of recommendations that will benefit the LPD 28 shipbuilding effort and all future U.S. Navy ship construction.

The research examines the previous work done by the LPD 17 Class SWAN Network Sustainment study team. This thesis includes a section that provides an overview of the SWAN, the Study team's findings, and the study team's recommendation to OPNAV.

The research also examines the shipboard network Capability Need Determination that drove the genesis of the CANES acquisition effort. In addition, the research examines the CANES Key Performance Parameters (KPPs) Key System Attributes (KSAs), and the CANES Systems Engineering Process.

Lastly, the research provides an overview of the Design Budget Process, including the core tenets of Design Budget and an example that highlighted the benefits of Design Budget. The research concludes that the Department of the Navy should make the decision to install CANES on LPD 28 during New Ship Construction by implementing the Design Budget Process in the effort to mitigate the risk of C4I equipment obsolescence at ship delivery.

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First and foremost, I would like to thank my thesis advisor, Dr. David Olwell, and my second reader, Dr. Ray Madachy. Completing my thesis was not easy at age 47 while working full time. There were many days when I wanted to quit. I also weathered great personal loss during the six years from the start of my involvement in the SEM-PD21 Program in 2009 to completing my thesis on my fourth and final extension request in 2015. Professor Olwell’s encouragement and commitment to follow through with me made all the difference in the world in keeping me moving ahead. I will be forever thankful for his patience, advice, and assistance with my thesis research and writing. He is proof that a good advisor can make all the difference in the world.

I would like to thank the leadership of PEO C4I for supporting my involvement in the SEM-PD21 Program and the members of the CANES Acquisition Program Management and Systems Engineering Team from the Tactical Networks Program Office at PEO C4I (PMW 160) in San Diego, for their willingness to share information and answer my many questions regarding CANES. In addition, I would like to thank the members of PEO Ships (PMS 317) who educated me on the SWAN and the challenges associated with SWAN sustainment.

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I. INTRODUCTION

A. BACKGROUND

In the late 1990s and early 2000s, the leadership of the Department of the Navy made a decision to embrace the use of Electronic Systems Integrators (ESIs) from the defense industry to lead the effort to design, develop, test, integrate, install, and sustain Commercially Furnished Equipment (CFE) networks onboard New Construction Ships still in the early development phase. Alliances between the shipbuilders and major defense contractors, such as Lockheed-Martin, Raytheon, and Northrop-Grumman emerged. The result was that three classes of new construction ships were delivered to the Navy with CFE Networks installed, as opposed to the traditional Government Furnished Equipment (GFE) Program of Record (POR) solution, such as the Integrated Shipboard Network System (ISNS), which is in place on the majority of U.S. Navy ships. The two primary cases of CFE networks include the Shipboard Wide Area Network (SWAN), which has been installed on the previous eleven LPD 17 Class ships, and the Total Ships Computing Environment (TSCE), which is the shipboard network installed on both the DDG 1000 Class ships and the Littoral Combat Ship (LCS). This proliferation of CFE Networks for has created new sustainability challenges that the Department of the Navy must face for the LPD 17, DDG 1000, and LCS 1 Class ships. The purpose of this research is to examine the sustainability challenge of the SWAN and provide specific recommendations for the future.

The speed of technological change in Command, Control, Communications, Computers, and Intelligence (C4I) systems, coupled with a suboptimal process for integrating C4I systems during New Ship Construction, has created a situation where new ships are often delivered to the Navy lacking the latest in C4I capabilities. This is due primarily to the fact that New Ship Construction, a defense acquisition term associated with shipbuilding that is sometimes identified as Shipbuilding and Conversion, Navy (SCN), requires that specific C4I equipment be identified at least one year prior to the contract award supporting ship construction. After the contract award, ship delivery itself can take another four to nine years, depending on the type, size, and complexity of the ship being constructed. This early requirement to identify specific C4I equipment has traditionally resulted in brand new ships being delivered to the Navy with dated and less than optimal C4I equipment suites installed onboard. This dynamic of rapid changes in technology, coupled with high profile examples of new construction ships being delivered to the Navy with out of date information technology systems and networks, created an opportunity for industry to propose to the Department of the Navy leadership that CFE solutions be adopted over traditional GFE as a cost savings measure.

With C4I equipment being predominantly information technology based, the impact of Moore's Law is highly relevant (Moore, 1965). Exponential improvements in Informational Technology-based systems are having a direct impact in how the Navy processes information onboard ships, airplanes, and submarines. If one considers Moore's Law in the context of the length of time it takes to build a ship, a process to improve C4I system procurement, delivery, installation, integration, and testing supporting New Ship Construction must be realized to avoid the risk of obsolescence.

One such New Ship Construction Program is the LPD 17 SAN ANTONIO Class, which consists of 11 amphibious transport dock ships originally designed to functionally replace over 41 amphibious ships that comprise the LPD 4, LSD 36, LKA 113, and LST 1179 classes. The mission of the LPD 17 Class is to embark, transport, and land elements of an embarked Landing Force, consisting of advanced amphibious assault vehicles (AAAVs), air-cushioned landing craft (LCACs), and the MV-22 Osprey tilt-rotor aircraft. The LPD 17 Class' increased vehicle space and substantial cargo carrying capacity makes the ships of this class a key element of twenty-first century Amphibious Readiness Groups, Expeditionary Strike Groups, or Joint Task Forces.

The first ship of the class, USS SAN ANTONIO (LPD 17), was commissioned in 2006. At present, LPDs 17 – 25 are currently in service to the U.S. Navy and LPDs 26 and 27 are currently under construction. The final ship, LPD 28, which will serve as a bridge to LX(R), the next generation of Amphibious Transport Dock ships, was recently authorized by Congress. LPD 28 is currently planned for delivery to the Navy in 2022.

The LPD 17 Class Acquisition Strategy (AS) called for the use of a Full Service Contractor to be the whole-life services provider to the Ship Acquisition Program Manager, NAVSEA PMS 317 (now PEO Ships, PMS 317), and be the subcontractor to the shipbuilder, formerly named Northrop Grumman Ship Systems (now Huntington-Ingalls Industries). As the Mission Systems Integrator, Raytheon was responsible for implementing a new ship design approach known as Total Ship System Integration (TSSI). Through this approach, Raytheon produced an architecture for the LPD 17 Class of ships that integrated 23 Contractor Furnished Equipment (CFE) systems along with 26 Government Furnished Equipment (GFE) systems.

One of the 23 CFE systems designed and installed on the LPD 17 Class ships by Raytheon is the Shipboard Wide Area Network (SWAN). The concept behind the SWAN was to design, build, test, and install a fully integrated shipboard network that incorporated the latest in commercially available information technology.

The purpose of the SWAN is to provide each ship with more than 1,000 data drops, serve as the fiber-optic backbone for 156 system-to-system interfaces, and provide mission critical connectivity in support of shipboard operations and warfighting. The hardware components making up the SWAN are enclosed in Raytheon-designed hardware systems that meet Military Specification MIL-S-901D Grade B shock requirements. The SWAN was designed to grow and adapt as information technology evolves. To this point, Raytheon proposed a technology refresh plan to NAVSEA with the aim of maintaining viability for the SWAN over the 40-year design-life of each LPD 17 Class ship.

Since delivery of the first ship in the LPD 17 Class in 2006, the Navy has had to invest significant capital over time to maintain the unique SWAN network, to train sailors on how to operate it, and to protect against emerging Cyber vulnerabilities. Considering the fact that there are 284 ships in service as of 16Feb15, this means that nine of those ships have the unique SWAN network installed, requiring dedicated financial and personnel resources tailored to the SWAN. Having to dedicate resources to the limited number of LPD 17 Class ships means less resources available to support the rest of the ships in the fleet that have Government Furnished Equipment (GFE) program of record networks installed. The mounting Total Ownership Costs (TOC) associated with the SWAN prompted OPNAV to reconsider the future of the SWAN on LPD 17 Class ships (O'Rourke, 2011).

In March 2011, the Resource Requirements Review Board (R3B) tasked OPNAV N2/N6 and N85 (now N95) to assess the future sustainment of the LPD 17 Class Network as part of the POM 14 process. In response to this tasking, OPNAV N2/N6 and N95 jointly authorized PEO C4I (PMW 160) and PEO Ships (PMS 317) to lead a cross functional study team for the purpose of providing recommendations for LPD 17 Class Network future.

The team conducted a requirements crosswalk, a method of mapping the functions of one system to another, to compare the network requirements of the LPD 17 Class (including the capabilities of the LPD 17 Class SWAN) with the Consolidated Afloat Network Enterprise System (CANES), the Navy's new Program of Record (POR) GFE shipboard network solution, which is currently being fielded in the Navy. The initial analysis involved the development and evaluation of nine Courses of Action (COAs), which were eventually reduced to three COAs regarding the future for sustainment of the LPD 17 Class shipboard network.

Though the study recommendation was endorsed by Navy leadership, a huge challenge remains in planning, coordinating, and executing the replacement of the existing SWAN network with CANES.

The LPD 17 Class SWAN Sustainment Study, jointly led by PEO C4I (PMW 160) and PEO Ships (PMS 317) in December 2011, recommended that the C4I Network portion of SWAN be replaced with CANES. The Assistant Secretary of the Navy for Research and Development (ASN RDA) accepted the recommendation of the study team and authorized OPNAV to resource replacement of the SWAN on the LPD 17 Class of ships (CNO OPNAV, 2011).

B. PURPOSE

The Shipboard Wide Area Network (SWAN) has been installed on the 10 previous ships of the LPD 17 Class and is currently being installed on LPD 27. However, with the recent decision by Congress to authorize funding for LPD 28, the Navy has the opportunity to implement the LPD 17 SWAN Sustainment study recommendation to install CANES, as opposed to the SWAN during New Ship Construction on LPD 28, which presents both opportunity and risk to the Navy.

Ship delivery, a New Ship Construction term synonymous with commissioning, for LPD 28 is currently planned for May 2022. Since it typically takes about seven years from contract award to ship delivery for a ship of the LPD 17 Class, the Request for Proposal (RFP) package, which must include enough detailed design information allowing the shipbuilder to review and submit a bid proposal, is expected to be released to the shipbuilder in October 2015.

Given the fact that the LPD 17 Class CANES design is not mature at this time, providing a firm Government Furnished Information (GFI) package to the shipbuilder in support of the RFP package release creates a dilemma for the Department of the Navy. The dilemma is whether to provide the older, mature design information associated with the SWAN, for which the shipbuilder has experience installing vs. providing the immature design information associated with CANES, which the LPD shipbuilder has never installed. Since CANES will go through at least one hardware refresh cycle between 2017 and 2022, the importance of implementing a flexible design approach is crucial to avoid information technology obsolescence issues at ship delivery. This situation represents a challenge that has faced New Ship Construction for the past 20 years, as systems complexity and technology has advanced. The fundamental question today is “What is the best way to meet the shipbuilder requirements for early GFI, while at the same time, allowing for advanced information technology to continue to mature so that the ship, when completed and delivered to the Navy, will have the latest and greatest in shipboard network technology installed?”

The purpose of this research was to examine the reason why the decision has been made to replace the C4I Network portion of SWAN with CANES, to closely evaluate the different courses of action considered in the SWAN Sustainment Study, to analyze the present challenge to maintain the SWAN Network across the LPD 17 Ship Class, and to examine the ongoing effort to design, develop, test, integrate, produce, install, and plan for sustainment of the LPD 17 Class CANES variant. In addition, the challenge to plan and coordinate the replacement of SWAN with CANES via the Navy Modernization Process was examined. Last, the thesis includes a summary of key points made, lessons learned captured, and recommendations for implementing the study's recommended course of action, including a potential first time CANES inline installation on an LPD 17 Class ship during New Ship Construction..

C. RESEARCH QUESTIONS

The effort to define, design, develop, build, integrate, test, produce, and install a C4I system onboard a Navy Ship is a great challenge in and of itself. However, the challenge to sustain the system over many years once it has been fielded can be just as daunting. One dilemma facing the Department of the Navy at present is whether to install an unsustainable CFE network onboard a New Construction Ship while the design information is firm for Shipbuilding purposes, or install the GFE Program of Record solution, while the design information is still under development. This is the classic New Ship Construction challenge where the alignment of Government Furnished Information (GFI) and Government Furnished Equipment (GFE) milestones supporting New Ship Construction and C4I system design, development, procurement, and delivery simply don not match up nicely. The basic problem is that the shipbuilder requires firm GFI early to support detailed design for Ship Construction, whereas the C4I system may still be in the development stage. A new process is needed that will meet both the needs of the shipbuilder and the Acquisition Program Office fielding the C4I System. The following questions were addressed in this research in order to thoroughly understand the challenge facing the Department of the Navy in planning for the installation of CANES onboard LPD 28 during New Ship Construction:

1. Why has the decision been made to replace the C4I network portion of SWAN with CANES on LPD 17 Class ships?
2. How should the recommendation of the SWAN Sustainment Study be implemented?
3. What specifically should be done to install CANES on LPD 28 during new construction as opposed to SWAN?

D. BENEFITS OF RESEARCH

The benefit of this research is that it examined the current processes in place at the shipbuilder regarding C4I network system installation, testing, and integration and provides improvement recommendations that will ultimately lower cost, schedule, and technical performance risk, while increasing C4I capability at Ship Delivery.

E. SCOPE AND METHODOLOGY

This thesis analyzed the challenge of avoiding information technology obsolescence at ship delivery when designing, procuring, testing, integrating, delivering, and installing C4I networks during New Ship Construction. The emphasis was on examining shipbuilder requirements to support New Ship Construction, while balancing against expected changes in information technology associated with C4I networks. Close examination of this very challenge was done for LPD 28.

F. LITERATURE REVIEW

The challenge of integrating information technology systems into large, complex projects requiring many years to complete necessitates a flexible design approach. This is true whether the project is to design and build a high-rise office complex, a jet aircraft, a warship, or a spacecraft. The challenge is figuring out how to engineer in ways during the construction process that will accommodate near term change and adaptability for technological improvements throughout the life cycle of the project.

The focus of this research was to examine the best method of replacing an older legacy CFE network with a GFE POR solution during New Ship Construction on final LPD 17 Class ship. During the course of this research, a literature review of topics directly related to the Design Budget Process, revealed that information is lacking. (The

Design Budget Process a process that PEO C4I has formally instituted and linked to the Systems Engineering Technical Review (SETR) process in support of New Ship Construction in the effort to minimize the risk of C4I systems obsolescence at ship delivery.) However, a fair amount of material has been produced on similar concepts, such as Pre-Planned Product Improvement (P3I) and technology insertion. A review of literature focused on P3I and technology insertion found that the fundamental challenge of avoiding information technology equipment obsolescence is a common theme throughout the Department of Defense, out in the commercial sector, and with the individual consumer.

A literature review was also conducted on the SWAN and CANES. Documents researched included the *LPD 17 Class SWAN Sustainment Stud*y completed in 2011 and a study completed by the RAND National Defense Research Institute titled *CANES Contracting Strategies for Full Deployment*. These documents are discussed in the following sections.

II. LPD 17 CLASS SWAN SUSTAINMENT OVERVIEW

A. INTRODUCTION

In March of 2011, when faced with a $99M Shipboard Wide Area Network (SWAN) sustainment bill across the FY13–17 Future Years Defense Program (FYDP) (PMS 317 POM 13 Issue Paper), the Requirements Review Board (R3B) tasked OPNAV N2/N6 and OPNAV N85 (now N95) to conduct a study of the LPD 17 Class Shipboard Network Architecture and provide a recommendation for the future: maintain the status quo with the Commercially Furnished Equipment (CFE) SWAN or retrofit the existing 11 LPD 17 Class ships with the new Government Furnished Equipment (GFE) systems known as CANES.

In turn, OPNAV N2/N6 and OPNAV N85 jointly authorized the Tactical Networks Program Office (PMW 160) within PEO C4I and the LPD 17 Class Ship Program Office (PMS 317) within PEO Ships to lead a cross-functional study team to assess the future of the LPD 17 Shipboard network.

The following sections provide background information on the SWAN network, CANES, and an overview of the SWAN Sustainment Study analysis, findings, and recommendation.

B. BRIEF OVERVIEW OF SWAN

1. SWAN Description

The SWAN is a subsystem of the LPD 17 Class Amphibious Transport Dock Ship Integrated Electronics System. The SWAN provides for transport, network management, system management, and end user functions and services for intra-system communications and inter-system communication and integration onboard LPD 17 Class ships.

The SWAN is composed of Ethernet networking elements, plus associated security elements, all interconnected via the network fiber optic cable plant. It provides the physical and logical connectivity defined by the baseline LPD 17 Total Ship

Information Management (TSIM) specification and supports the distribution of shipboard voice, digital video and digital data (Raytheon, 2007).

2. SWAN "As Is" Architecture

The SWAN is currently deployed in two variants: Gigabit Mesh and Gigabit Ring. Table 1 below provides a summary of which architecture variants are installed on each of the LPD 17 Class ships.

Ship	Network Architecture Type
LPD 17–18	Gigabit Mesh
LPD 19–21	Gigabit Ring
LPD 22–25	Gigabit Mesh
LPD 26–27	Gigabit Ring

Table 1. LPD 17 Class Network Configuration Type

In the Gigabit Mesh architecture, as depicted in Figure 1, the SWAN core switches are connected in a full mesh topology where each node captures and sends its own data and relays the data on to other nodes, while the edge switches, routers, servers, and other devices are connected in a star topology, where one central hub connects the other nodes in the network (Raytheon 2009).

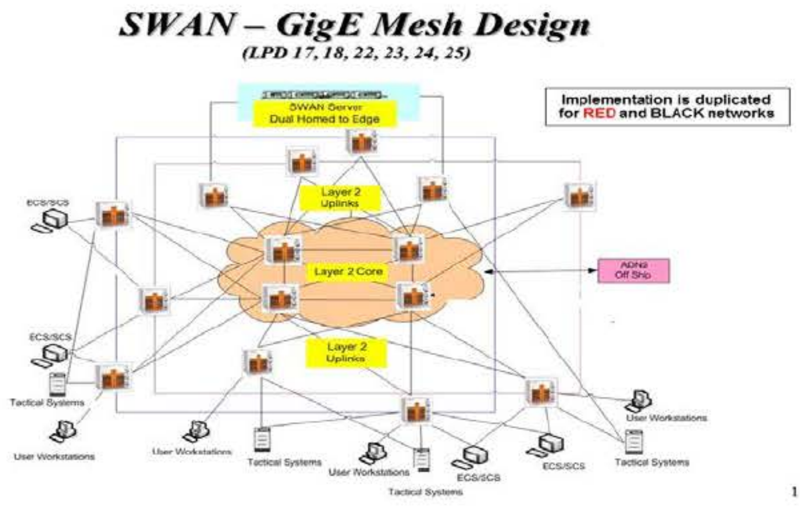

Figure 1. SWAN GigE Mesh Design (from CNO OPNAV 2011)

In the Gigabit Ring architecture, as depicted in Figure 2, the SWAN core switches are dual connected to each other, while the router and servers are dual connected to the core switches. Edge switches are connected in a ring topology (Raytheon 2009).

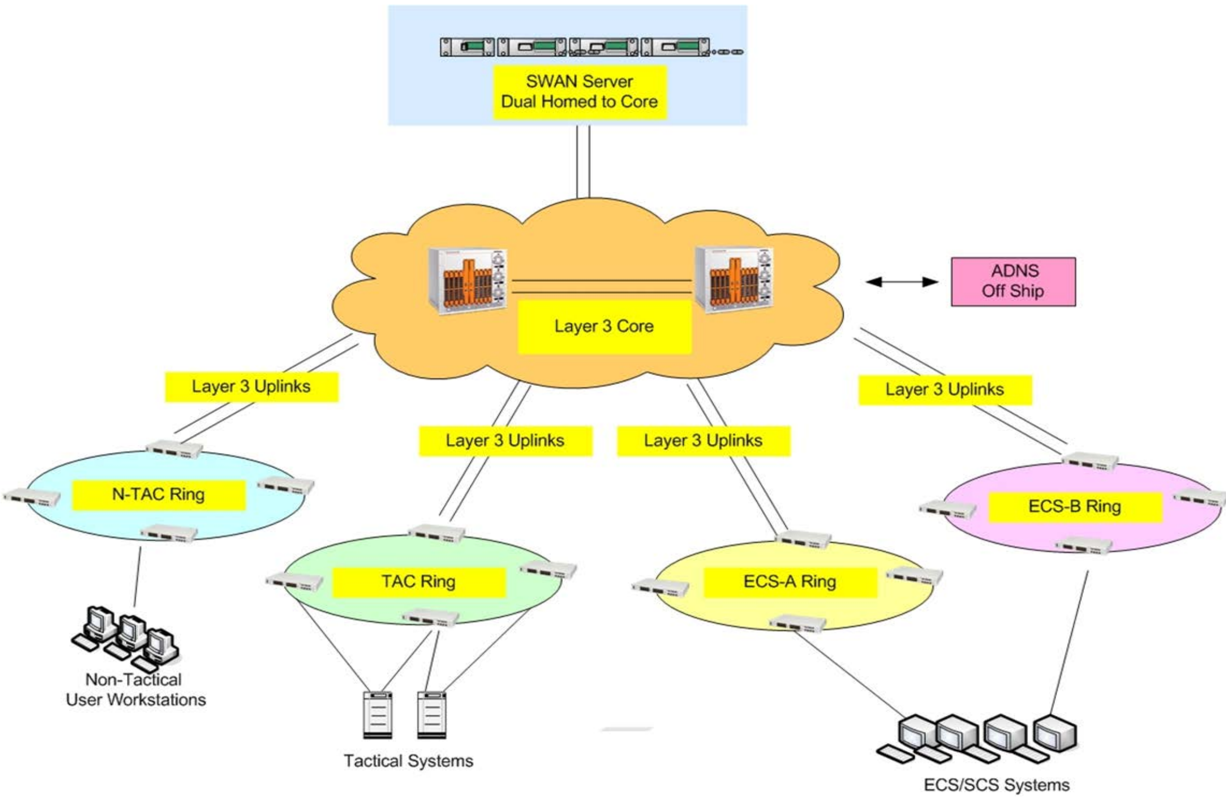

Figure 2. SWAN GigE Ring Design (from CNO OPNAV 2011)

The SWAN is essentially the shipboard network infrastructure onboard LPD 17 Class ships that integrates a number of shipboard electronic systems. These systems include the Ship Control System (SCS), the Navigation Data Distribution System (NDDS), the Magnetic Signature Control System (MSCS), the Engineering Control System (ECS), and the Command Information Display System (CIDS). These systems are integrated into a Common Computing Environment (CCE) for LPD 17 Class Ships, where multiple networks were replaced with one complete shipboard network, capable of providing all the physical and logical connections necessary to support the transport of C4I, HM&E, and navigation data, and allow for the hosting of government furnished software applications, such as Global Command and Support System – Maritime (GCCS-

M), Naval Tactical Command Support System (NTCSS), and Common PC Operating System Environment (COMPOSE) (Raytheon, 2007). At the time of its proposal for installation on LPD 17, the SWAN was actually a transformational and revolutionary approach for shipboard networks. At that time, all government furnished shipboard networks were stove-piped, meaning that the networks stood alone and were not integrated.

Figure 3 depicts the current functional architecture of the SWAN onboard LPD 17 Class ships.

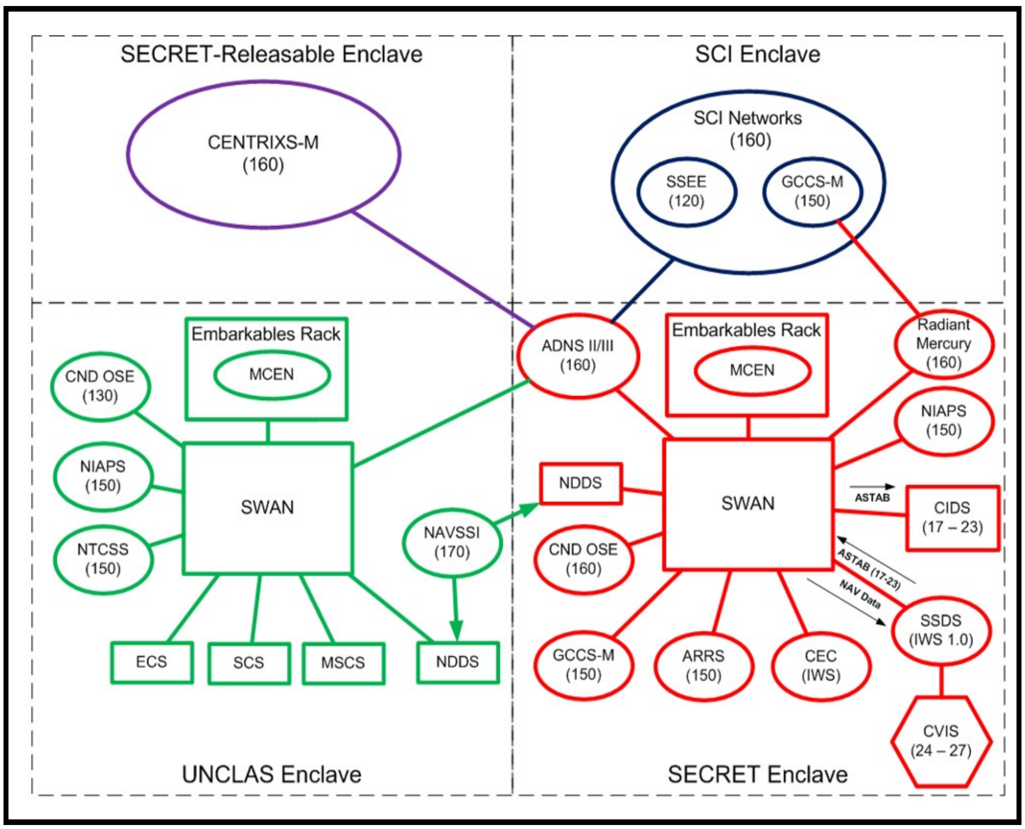

Figure 3. SWAN Functional Architecture (from CNO OPNAV 2011)

C. BRIEF OVERVIEW OF CANES

1. CANES Description

The Consolidated Afloat Networks Enterprise System (CANES) is a Program Executive Office (PEO) Command, Control, Communications, Computers, and Intelligence (C4I) Program of Record (POR) system that is currently being fielded on

U.S. Navy ships. CANES serves as the bridge to the future for afloat networks onboard Navy ships and is fully supported. And, like the SWAN, CANES consolidates a number of existing legacy and standalone networks onboard Navy ships. CANES provides the necessary shipboard infrastructure for applications, systems, and services to operate in the tactical domain and delivers its capabilities within a single complete system, bringing the necessary hardware onboard ship to enable the timely exchange of information among tactical, support, and administrative users. Figure 4 provides a logical network view of CANES across the Unclassified, Secret, Secret Releasable/Coalition, and SCI enclaves.

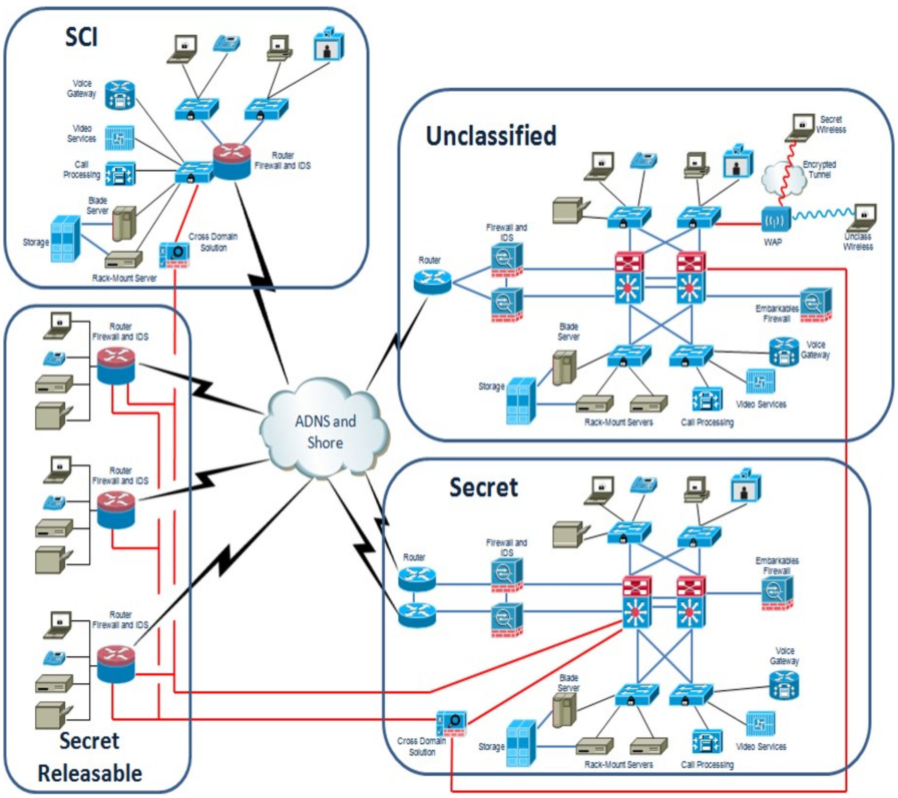

Figure 4. CANES Network Design Logical View (from PEO C4I 2009)

CANES is a mostly a commercial-off-the-shelf (COTS)-based system, including hardware, software, storage devices, and end user devices operating across the four enclaves identified in Figure 4. In addition, CANES provides for the hosting of applications that support C4ISR, logistics, and business domains.

The CANES Program has implemented a four–year hardware refresh cycle and a two-year software refresh cycle in the effort to mitigate obsolescence issues and to provide for a stable and predictable configuration and modernization roadmap. CANES specifications have been developed to promote an open, modular, and scalable design. It is anticipated that future baselines will incorporate new advances in information technology in the effort to expand the network capabilities delivered to the fleet with CANES (PEO C4I 2009).

D. SWAN SUSTAINMENT STUDY OVERVIEW

1. Introduction

The initial effort of the SWAN sustainment analysis involved the development and analysis of nine courses of action (COAs), which were eventually reduced three COAs regarding the future sustainment of the SWAN. The SWAN Sustainment Study team used a Balanced Scorecard Approach to provide for a quantitative analysis of the cost, schedule, benefits, and risks of each COA. The COA analysis included a review of the costs to cover the necessary engineering, sustainment, and modernization efforts in support of a Program Objective Memorandum (POM) submission for FY14 for the recommended COA (CNO OPNAV 2011).

2. COA Overview

The study team first examined three general COAs regarding the task to examine the future sustainment of the LPD 17 Class SWAN network. The three general COAs included:

- COA 1 (Full SWAN Model): This COA was basically to maintain the status quo, where NAVSEA would maintain programmatic responsibility for the SWAN and Raytheon would continue on as the In Service Engineering Agent (ISEA) for the CFE Network.
- COA 2 (Full CANES Model): This COA considered expanding CANES, wherein CANES would replace SWAN in its entirety.
- COA 3 (Federated Approach): This COA considered breaking the SWAN into a separate HM&E Network and then having CANES take over the C4I Network portion of SWAN only.

- The study team then compiled the requirements of both the SWAN and CANES, and did a requirements crosswalk to analyze the three COAs listed above. As a result of the requirements crosswalk, the three COAs were expanded to the following nine COAs:
- COA 1A: SWAN Enclave Hardware Expansion
- COA 1B: SWAN + CANES (SR and SCI Enclaves only)
- COA 1C: SWAN Enclave Hardware and Software Expansion
- COA 1D: Adopt SWAN plus CANES (SR and SCI only) as a PEO C4I POR
- COA 2A: Full CANES
- COA 2B: Full CANES + SWAN Connected Systems
- COA 3A: CANES Federated w/ SWAN (HM&E only)
- COA 3B: CANES Federated w/ NSWC HM&E POR Solution
- COA 4: Modernize SWAN to CANES requirements

The study team then used a Balanced Scorecard Approach, which is a standard method of objectively scoring multiple options, to analyze the nine COAs listed above and selected three COAs for more detailed analysis. The three COAs chosen were:

- COA A: SWAN Enclave Hardware Expansion
  - Expand/upgrade the SWAN hardware to meet CANES requirements
  - Continue with the integrated C4I and HM&E Network
- COA B: CANES Federated with NAVSEA HM&E POR Network
  - C4I Network portion of SWAN replaced by CANES
  - Navigation Data Distribution System (NDDS) integrated with HM&E network
  - NAVSEA POR HM&E network established and in place of SWAN HM&E network
- COA C: CANES Federated with NSWC CD HM&E POR Network
  - C4I Network portion of SWAN replaced by CANES

- NDDS provided by Raytheon as a connected system to the NSWC CD HM&E Network
- NSWC CD POR HM&E network established and in place of SWAN HM&E network

3. CANES / SWAN Capabilities Comparison

In order to identify the impact of migrating the C4I network portion of the SWAN on the LPD 17 Class ships to CANES, the capabilities of the SWAN, and all C4I network systems connected to the SWAN, had to be identified and compared against the projected capabilities of CANES and the projected CANES connected systems. To support this comparison, the study team built a comparison matrix and conducted a requirements crosswalk between CANES requirements and the requirements of the SWAN. This requirements crosswalk was used to determine where capability and requirements gaps existed between the SWAN and CANES. Table 2 summarizes SWAN capabilities for the LPD 17 Class ships and CANES capabilities per the CANES Functional Specification (version 1.3.3) as they apply to each of the COAs listed above.

Table 2. SWAN/CANES Capabilities Comparison to COAs (from CNO OPNAV 2011)

Capability (current)	SWAN	CANES	COA A	COA B	COA C
Application Hosting	No	Yes	Included	Included	Included
Enterprise Software Baseline	Yes (COMPOSE)	Yes (CANES)	Included	Included	Included
Compute Resources Infrastructure (Servers, NW Storage)	Yes	Yes	Included	Included	Included
Computer NW Defense Operating Sys Environment (CND-OSE)	Connected	Yes	Use GFE SW	Included	Included
Cross Domain Solution	Connected	Yes	NRE to provide	Included	Included
Encryption	Connected	Yes	NRE to provide	Included	Included
Enterprise Network System Management (ENMS)	Connected	Yes	Use GFE SW	Included	Included
External Wireless (Unclass)	No	Yes	NRE to provide	Included	Included
Internal System Management	Yes	Yes	Use GFE SW	Included	Included
Internal Wireless (Secret)	No	Yes	NRE to provide	Included	Included
Internal Wireless (Unclass)	Yes	Yes	Included	Included	Included

Capability (current)	SWAN	CANES	COA A	COA B	COA C
NAV Data Distribution (NDDS)	Yes	No	Included	Use CFE System	Use CFE System
Net Centric Enterprise Svcs (NCES) - Joint/Allied/Global Info Grid (GiG)/Coalition Interoperability	Yes	Yes	Use GFE SW	Included	Included
Network Transport	Yes	Yes	Included	Included	Included
NTP Time Distribution (Stratum)	Yes	Yes	Included	Included	Included
Personal Digital Assistant (PDA) Services	No	Yes	NRE to provide	Included	Included
Solaris Operating System Support, Global Command and Control System-Maritime (GCCS-M) Hosting	Yes	Yes	NRE to provide	HW Included, Use GFE SW	HW Included, Use GFE SW
Video Distribution	Connected	Yes	NRE to provide	Included	Included
Video Tele Conference (VTC)	Connected	Yes	NRE to provide	Included	Included
Voice Over IP (VoIP) Secret/SR/SCI	Connected	Yes	Only for SCI-Provide HW, Use GFE SW	Included	Included

Definitions:
Included- Already part of existing baseline
Use GFE SW - Requires Government-Furnished SW (CANES or other POR)
NRE to provide - Requires additional Non Recurring Engineering to provide capability
Connected - Not part of Baseline; fielded as independent system connected to SWAN/CANES transport

Since CANES includes the former stand-alone C4I legacy networks the analysis by the study team also had to include those C4I systems that were connected to the SWAN. Table 3 provides a comparison of the hosted applications and connected systems currently on the SWAN, CANES, and included with each of the three COAs.

Table 3. SWAN/CANES Hosted & Connected Systems Capability Comparison (from CNO OPNAV 2011)

Supported Systems (current)	PARM	SWAN	CANES	COA A	COA B	COA C
Afloat Readiness Reporting System (ARRS)	PMW 150	Connected	Hosted	Hosted, Use GFE SW	Hosted, Use GFE SW	Hosted, Use GFE SW
Automated Digital Network System (ADNS) Interface	PMW 160	Connected	Connected	Connected	Connected	Connected
Combat Systems – Cmd Info Dsply Sys (CIDS) or Common Visual Information Sys (CVIS)	COA Dependent	Connected	Connected	Provided by Video Distribution (COA Dependent)		
Combat Systems – Cooperative Engagements Capability (CEC)	PEO IWS	Connected	Connected	Connected	Connected	Connected
Combat Systems – Ship's Self Defense System (SSDS)	PEO IWS	Connected	Connected	Connected	Connected	Connected

Supported Systems (current)	PARM	SWAN	CANES	COA A	COA B	COA C
Combined Enterprise Regional Information Exchange Sys- Maritime (CENTRIXS-M)	PMW 160	COA Dependent	CANES Subsumes	NRE to provide HW, Use GFE SW	CANES Subsumes	CANES Subsumes
US Marine Core (USMC) - Servers and Operating System SW	MARFOR SYSCOM	Connected	Hosted	Hosted, Use GFE SW	Hosted, Use GFE SW	Hosted, Use GFE SW
Global Command and Control System-M (GCCS-M)	PMW 150	Connected	Hosted	Hosted, Use GFE SW	Hosted, Use GFE SW	Hosted, Use GFE SW
Hull Mechanical & Elect (HM&E) - Engr Control Sys (ECS), Integrated Condition Assmt Sys (ICAS)	PMS 470	Connected	Connected	Connected	Connected, NRE to segregate SWAN	Connected, NRE to develop HM&E
Hull Mechanical & Electrical (HM&E) - Damage Control Action Management System (DCAMS)	COA Dependent	Connected	NA	Connected	Connected, NRE to segregate SWAN	Connected, NRE to develop HM&E
Hull Mechanical & Electrical (HM&E) - Magnetic Signature Control System (MSCS)	Raytheon/ NSWC	Connected	NA	Connected	Connected, NRE to segregate SWAN	Connected, NRE to develop HM&E
Hull Mechanical & Electrical (HM&E) - Steering Control System (SCS)	COA Dependent	Connected	NA	Connected	Connected, NRE to segregate SWAN	Connected, NRE to develop HM&E
NAV Data Distribution (NDDS)	Raytheon	Connected	NA	Connected	Connected, Hotels for NDDS as HW, NRE to integrate	Connected, Hotels for NDDS as HW, NRE to integrate
Naval Tactical Command Support System (NTCSS)	PMW 150	Connected	Hosted	Hosted, Use GFE SW	Hosted, Use GFE SW	Hosted, Use GFE SW
Navigation Sensor System Interface (NAVSSI)	PMW 170	Connected	Connected	Connected	Connected	Connected
Navy Information Application Product Suite (NIAPS)	PMW 240	Connected	Hosted	Hosted, Use GFE SW	Hosted, Use GFE SW	Hosted, Use GFE SW
Sensitive Compartmented Information (SCI) Network Computing Infrastructure or Transport	PMW 160	Independent PMW 160 POR	CANES Subsumes	NRE to provide HW, use GFE SW	CANES Subsumes	CANES Subsumes
Ship's Signal Exploitation Equipment (SSEE)	PMW 120	Connected To SCI	Connected	Connected	Connected	Connected

4. Requirements Crosswalk Analysis

Comparing the SWAN and CANES requirements provided the study team with great insight into the functions accomplished by the SWAN and CANES, as well as the performance parameters to which each system is validated. The requirements were segregated into two major categories:

- CANES requirement statements not met by SWAN requirements
- SWAN requirement statements not met by CANES requirements

There are 1,562 CANES requirements (PEO C4I 2009) and there are 482 SWAN requirements (Raytheon 2009). Figure 5 shows how the SWAN and CANES requirements map to each other.

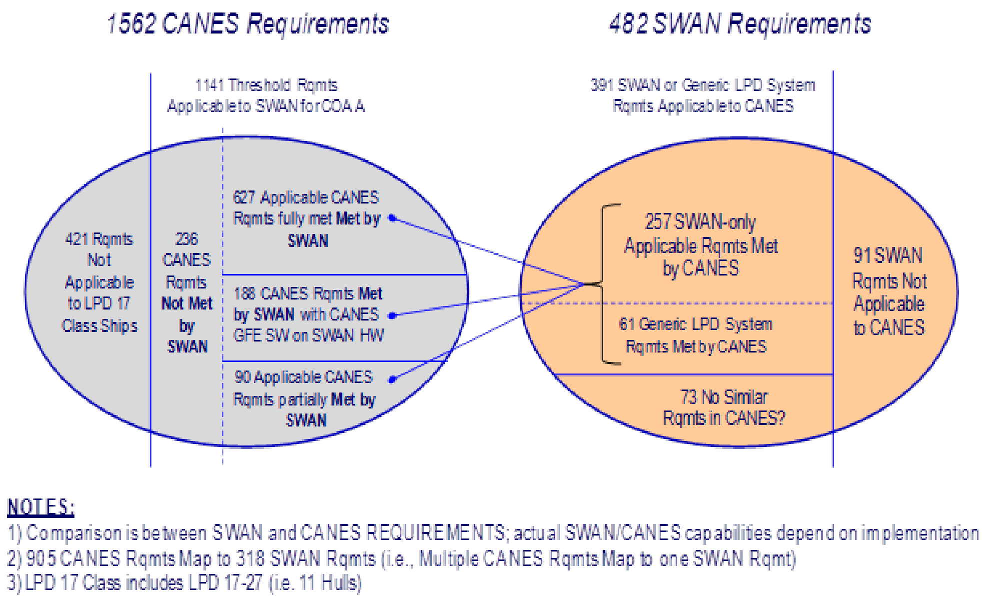

Figure 5. SWAN/CANES Requirements crosswalk (from CNO OPNAV 2011)

The requirements mapping in Figure 5 shows that 905 CANES requirements map to 318 SWAN requirements, which means that there are cases where multiple CANES requirements map to one SWAN requirement. Here are four key takeaways from the SWAN/CANES Requirements crosswalk completed by the study team:

- 236 CANES requirements are not met by the SWAN
- 421 CANES requirements are not applicable to the LPD 17 Class ships
- 73 SWAN requirements have no similar CANES requirement
- 91 SWAN requirements are not applicable to CANES

5. COA Analysis

The LPD 17 Class SWAN Sustainment Study team used the Delphi method to evaluate each COA (CNO OPNAV, 2011). In using this approach, shipboard network subject matter experts (SMEs) were identified and involved in both the development of specific selection criteria and the voting process. To score each of the COAs, the Balanced Scorecard Approach, which is a quantitative method of evaluating alternatives based on a variety of defined criteria, was used to determine which COA provided the best value to the Navy. The following criteria were used to select the best COA:

- Total Ownership Cost (TOC)
- Development schedule
- Required modernization AVAIL window
- Ability to leverage existing sustainment & support infrastructure
- Risk
- Impact to training pipeline / Integrated Logistical Support (ILS)
- Technical interoperability

Over the course of three In Process Review (IPR) periods, data was collected and analyzed for each of the three COAs. The study team evaluated each of the COAs against the established criteria and scored them using the Balanced Scorecard approach. Table 4 shows the definitions for the scoring criteria used by the study team to evaluate the COAs.

	Criterion	Red: 1	Yellow: 3	Green: 5
QUANTITATIVE CRITERIA	**Total Ownership Cost (TOC)**	TOC (FY14 - 27) > $600M	TOC (FY14 - 27) <= $600M	TOC (FY14 - 27) <= $500M
	Schedule	COA Development Schedule >24 months	COA Development Schedule <= 24 months	COA Development Schedule <= 18 months
	Modernization	Required Availability > 5 months	Required Availability <= 5 months	Required Availability <= 3 months
	Sustainment / ISEA	- Class-Specific Help Desk - Class-Specific ISEA Team and practices	- Leverages common Help Desk with fleet - Class-Specific ISEA Team and practices	- Leverages common Help Desk with fleet - Common ISEA Team and practices across multiple platforms
QUALITATIVE CRITERIA	**Risk**	Overall COA Average Risk Score >15	Overall COA Average Risk Score < 15	Overall COA Average Risk Score < 8
	Training/ILS	Significant impact to training pipeline: - Requires development of new training packages independent of PEO C4I PoR training packages - No commonality with PEO C4I Baseline	Some impact to training pipeline: - Requires modification of existing PEO C4I PoR training packages - Leverages common components from PEO C4I PoR Baseline	Minimal impact to training pipeline: - No additional training packages required - Common with PEO C4I PoR Baseline
	Technical Interoperability	- Technical COA Average Risk Score > 15 - Dedicated SIT outside current PEO C4I PoR	- Technical COA Average Risk Score < 15 - Dedicated SIT outside current PEO C4I PoR	- Technical COA Average Risk Score < 8 - Delta SIT from existing PEO C4I PoR solution

Table 4. LPD 17 Study team Balanced Scorecard Criteria Definition Table (from CNO OPNAV 2011)

To highlight one example of the study team's efforts to collect data and conduct analysis, Table 5 shows a summary of the TOC for each of the three COAs. As Table 4 shows, COA B has the lowest cost to implement across the FYDP at $169.7M and the lowest TOC from FY14 to FY27 at $412.7M.

COA A	FY14	FY15	FY16	FY17	FY18	FYDP Total	TOC (FY14 - 27)
RDT&E	$ 6,989.62	$ -	$ 1,801.36	$ -	$ 6,989.62	$ 15,780.59	$ 33,362.55
OPN	$ 68,540.08	$ 93,624.30	$ 59,354.26	$ 12,542.11	$ 17,135.02	$ 251,195.76	$ 679,000.56
OMN	$ 4,005.24	$ 9,601.11	$ 9,313.73	$ 6,228.42	$ 3,286.79	$ 32,435.28	$ 84,902.79
COA A Total	**$ 79,534.93**	**$ 103,225.41**	**$ 70,469.35**	**$ 18,770.52**	**$ 27,411.42**	**$ 299,411.64**	**$ 797,265.90**
COA B	FY14	FY15	FY16	FY17	FY18	FYDP Total	TOC (FY14 - 27)
RDT&E	$ 2,137.00	$ -	$ 333.45	$ -	$ 979.58	$ 3,450.04	$ 6,076.11
OPN	$ 35,183.88	$ 50,300.00	$ 33,377.74	$ 8,243.72	$ 8,493.08	$ 135,598.42	$ 331,583.94
OMN	$ 3,324.21	$ 5,797.08	$ 6,443.69	$ 8,041.18	$ 7,029.61	$ 30,635.77	$ 75,028.39
COA B Total	**$ 40,645.10**	**$ 56,097.07**	**$ 40,154.88**	**$ 16,284.89**	**$ 16,502.27**	**$ 169,684.22**	**$ 412,688.43**
COA C	FY14	FY15	FY16	FY17	FY18	FYDP Total	TOC (FY14 - 27)
RDT&E	$ 3,270.11	$ -	$ 338.62	$ -	$ 614.47	$ 4,223.20	$ 6,129.38
OPN	$ 39,860.35	$ 58,798.23	$ 39,531.91	$ 10,132.80	$ 9,633.16	$ 157,956.45	$ 350,729.04
OMN	$ 4,330.60	$ 6,492.36	$ 7,149.00	$ 8,946.02	$ 8,093.50	$ 35,011.48	$ 86,635.46
COA C Total	**$ 47,461.06**	**$ 65,290.59**	**$ 47,019.54**	**$ 19,078.81**	**$ 18,341.12**	**$ 197,191.13**	**$ 443,493.87**

Table 5. COA Total Ownership Cost (TOC) Summary (from CNO OPNAV 2011)

E. SWAN SUSTAINMENT STUDY RECOMMENDATION

Based on analysis of each COAs cost, assessed risk, and the other selection criteria, the LPD 17 Network Study team recommended COA B, the Federated Network approach with CANES as the C4I Network and a NAVSEA POR established for the HM&E Network. COA B was evaluated as having the lowest TOC and risk. In addition, COA B was considered to be more technically feasible and best aligned with current Navy PORs. Table 5 shows the Balanced Scorecard results from the study team's evaluation of the three COAs.

	Criterion	COA A	COA B	COA C
QUANTITATIVE CRITERIA	Total Ownership Cost (TOC)	TOC (FY14 - 27): $797M	TOC (FY14 - 27): $413M	TOC (FY14 - 27): $443M
QUANTITATIVE CRITERIA	Schedule	COA Development Schedule: 15 Months	COA Development Schedule: 15 months	COA Development Schedule: 15 months
QUANTITATIVE CRITERIA	Modernization	Required Availability: 3 months	Required Availability: 3 months	Required Availability: 3 months
QUANTITATIVE CRITERIA	Sustainment / ISEA	-Class-Specific Help Desk - Class-Specific ISEA Team and practices	-Leverages Existing PEO C4I -Help Desk and ISEA Practices --ISEA team spread across multiple platforms	-Leverages Existing PEO C4I -Help Desk and ISEA Practices --ISEA team spread across multiple platforms
QUALITATIVE CRITERIA	Risk	Overall COA Average Risk Score : 9.7	Overall COA Average Risk Score : 4.9	Overall COA Average Risk Score : 5.6
QUALITATIVE CRITERIA	Training/ILS	Significant impact to training pipeline: - Requires development of new training packages independent of PEO C4I POR training packages - No commonality with PEO C4I Baseline	Some impact to training pipeline: - Requires modification of existing PEO C4I POR training packages - Leverages common components from PEO C4I POR Baseline	Some impact to training pipeline: - Requires modification of existing PEO C4I POR training packages - Leverages common components from PEO C4I POR Baseline
QUALITATIVE CRITERIA	Technical Interoperability	-Tech Risk Score: 10 - Dedicated SIT outside current PEO C4I POR	- Tech Risk Score: N/A - Delta SIT from existing PEO C4I POR solution	- Tech Risk Score: N/A - Delta SIT from existing PEO C4I POR solution

Table 6. LPD 17 Network Study team Balanced Scorecard Results (from CNO OPNNAV 2011)

F. CHAPTER SUMMARY

In March 2011, OPNAV was presented with a significant cost of $99M to sustain the SWAN from FY13 to FY17 on 11 LPD 17 Class ships. In today's resource constrained environment, the Department of the Navy leadership decided to consider other alternatives in the effort to mitigate this cost. And, as a result, the LPD 17 Network Study team was created to consider COAs for the LPD 17 Class shipboard network and to provide a recommendation for implementation.

Over the course of nine months from March 2011 to December 2011, the LPD 17 Network Study team identified nine potential COAs, determined the three best COAs, collected extensive data supporting each COA, and conducted detailed analysis on the three COAs. Three In Process Reviews (IPRs) were held reporting on the evaluation of the progress on COA to OPNAV and Navy Leadership.

Using the Balanced Scorecard approach to evaluate the COAs, the study team determined that the best alternative would be to federate the SWAN Network on LPD 17 Class ships by replacing the C4I Network portion of SWAN with CANES and by replacing the HM&E Network portion of SWAN with a new POR HM&E Network to be established at NAVSEA. This approach was evaluated as being the most cost effective for the long term, having the least amount of risk, and as having the lowest impact to the Navy as a whole to implement with respect to training, ILS, and existing In Service Engineering Agent (ISEA) support.

In January 2012, the LPD 17 Network Study was officially delivered to OPNAV N85 (now N95), OPNAV N2/N6, and ASN (RDA) (the Assistant Secretary of the Navy for Research, Development, and Acquisition). The study recommendation was accepted and approved for implementation. With approval granted, POM issue papers were submitted to OPNAV in support of POM 14 by the CANES Program from the Tactical Networks Program Office from PEO C4I (PMW 160) requesting funding to develop an LPD 17 Class variant of CANES and to procure CANES Production Units for fielding on the In Service LPD 17 Class ships during AVAIL windows spanning FY14 – FY18.

Unfortunately, the government shutdown and the subsequent impact of sequestration put a two-year delay in the LPD 17 CANES development and fielding effort. So, good momentum from the study team's effort was lost. However, the development effort is now back on track, with the LPD 17 CANES variant design expected to be completed by July 2015, and the first LPD 17 Class CANES Modernization AVAIL install planned to start in October 2016 on LPD 18 (NEW ORLEANS).

The challenge now facing the Department of the Navy is whether to modify the existing LPD 17 shipbuilding contract, by including CANES in the Request For Proposal (RFP) scheduled to be released to the shipbuilder in October 2015. If the decision is made to install CANES during New Ship Construction, it will be in line with the LPD 17 Network Study recommendation. However, it will be a change to the Shipbuilding Contract, which will impact the shipbuilder. On the other hand, if the decision is made to stay with the SWAN on LPD 28, the Navy faces the old dilemma of a New Construction Ship delivering to the Navy in the 2022 – 2023 timeframe with an outdated information technology system installed that must immediately be removed and replaced with a newer system during the first Modernization AVAIL window, which is a great waste of the taxpayer's money. The reminder of this research will focus on the effort to align the LPD 17 CANES variant design and development effort to the LPD 28 New Ship Construction effort.

III. DESIGNING, INTEGRATING, AND TESTING CANES

A. INTRODUCTION

The fielding of new C4I systems onboard U.S. Navy warships is a complex effort requiring close coordination between many entities operating within the DOD 5000 Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System, which is comprised of the Joint Capabilities Integration and Development System (JCIDS), the Defense Acquisition System, and the Planning, Programming, Budgeting, and Execution Process (PPBE Process). As stated in DOD Directive 5000.1, "The Defense Acquisition System exists to manage the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. The investment strategy of the Department of Defense shall be postured to support not only today's force, but also the next force, and future forces beyond that. The primary objective of Defense Acquisition is to acquire products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner, and at a fair and reasonable price."

One such C4I system currently being fielded onboard Navy ships with the objective of satisfying warfighter needs with measurable capability improvements is CANES, which is an Acquisition Category (ACAT) IA Major Automated Information System (MAIS) Program managed by Program Executive Office, Command, Control, Communications, Computers, and Intelligence (PEO C4I). The CANES initiative was developed in collaboration with the Naval FORCEnet Enterprise (NNFE) as a framework to fundamentally enhance C4ISR capabilities in the Fleet. As stated in the CANES Acquisition Strategy, the four primary goals of CANES include the following:

- Provide a secure afloat network for Naval and Joint Operations.
- Consolidate and reduce the number of afloat networks through the use of Common Computing Environment (CCE) and mature cross domain technologies.

- Reduce the infrastructure footprint and associated Logistics, Sustainment, and Training costs.
- Increase reliability, security, interoperability, and application hosting to meet current and projected warfighter requirements.

Fundamentally, CANES is an effort focused on consolidating all C4I afloat networks into a single network that provides Navy ships with a Common Computing Environment (CCE), Cross Domain Solutions (CDS), and delivers a foundation for achieving a Services Oriented Architecture (SOA) by providing a common set of tailored Afloat Core Services (ACS).

Today, there are four primary shipboard C4I networks on U.S. Navy ships: the NIPRNET (the Unclassified Network), the SIPRNET (the Classified Network), the Sensitive Compartmented Information (SCI) Network, and the Combined Enterprise Regional Information Exchange System (CENTRIXS), each operating at different security levels. Additionally, there are a number of non POR systems that support video data exchange and distribution onboard ship, such as the Video Information Exchange System (VIXS) and Ships Video Distribution Systems (SVDS). The results of a survey conducted by the Tactical Networks Program Office within PEO C4I in 2010 revealed the extent of network variance regarding the status of legacy shipboard networks:

- 642 legacy systems on 300+ Navy platforms
- 162 Integrated Shipboard Networking System (ISNS) systems (17+ variants)
- 151 CENTRIXS systems (four variants)
- 144 SCI Networks systems (ten variants)
- 50 Submarine Local Area Network (SubLAN) systems (eight variants)
- 102 VIXS systems (five variants)

Given the proliferation of CFE Networks, such as the SWAN on LPD 17 Class ships and the TSCE on the Littoral Combat Ship (LCS), one can readily see that the great number of disparate C4I networks presents a significant challenge to the Navy with respect to life cycle sustainment, cyber security, and the training of Navy sailors.

OPNAV saw this as a major problem and determined that the status quo was not sustainable. In addition, OPNAV was concerned that the older legacy networks did not support rapid technology insertion and/or capability expansion. Additionally, it was determined that the shipboard network infrastructure did not support the Navy's way ahead for Net-centric Warfare or for interfacing with the Global Information Grid (GIG). The OPNAV review revealed a number of capability gaps in four primary areas: (a) System Interoperability and Responsiveness; (b) Collaboration; (c) Information Access & Exchange; (d) Cross-Domain Solutions (CANES CDD). PEO C4I was funded by OPNAV to initiate a program to address the four primary capability gaps identified above, regarding shipboard networks. The CANES Program was established in 2008 to satisfy these capability gaps and to develop a solution to meet the warfighter's shipboard network capability needs and eliminate the great degree of network variance existing on Navy afloat platforms.

After a successful Gate 6 Review conducted in December of 2012, CANES received Milestone C approval in February of 2013 and entered the Limited Deployment Fielding Phase of the Program. CANES is currently in the Full Deployment phase of the program, with installations either completed and/or in progress on 20 ships as of March 2015. However, no CANES installations have been completed as yet for any of the LPD 17 Class ships. LPD 28 would be the first opportunity for the Navy to make the decision to replace a major CFE shipboard C4I network with a GFE POR solution during New Ship Construction. In light of the great number of disparate C4I networks already in service on U.S. Navy ships, serious consideration must be granted to installing CANES on LPD 28 during New Ship Construction in the attempt to eliminate variance, reduce total life cycle sustainment costs, and increase protection against cyber threats.

B. CAPABILITY NEED DETERMINATION

The JCIDS Process involves an analysis of Doctrine, Organization, Training, Material, Leadership, Education, Personnel, and Facilities (DOTMLPF) in an integrated, collaborative process to define gaps in warfighting capabilities and propose solutions (Joint Chiefs of Staff 2015). As stated in the previous section, OPNAV conducted a review of shipboard network capabilities out in the Fleet in the 2008 timeframe and identified four major C4I network capability gaps. OPNAV's gap analysis led to the creation of the CANES Program to address the identified gaps in capability.

The end state goal of CANES is to provide a single C4I network infrastructure onboard Navy ships that leverages Multi-Level Security (MLS) and Afloat Core Services (ACS) architectures. Table 7 lists the capabilities that CANES is to provide to Navy Afloat units (PEO C4I, 2009).

CANES System Capabilities
Voice
IP Telephony
* To include mobile and stationary end points; secure and unsecure communications
Video
Video Teleconferencing
* To include point-to-point and point-to-multi-point
Video / Graphics Distribution
* To include video broadcast distribution and data wall/large screen display capabilities
Data Services
Network Support
* To include Common Network Services; Network Identity Lifecycle Management; Network Access Management
Information Management
* To include Application Hosting, Server Based Databases; Print Services; Peripheral Devices; Email & Calendar Services; Office Productivity & Automation; Messaging Tools; Collaboration Tools; Knowledge Management; Core Infrastructure
Core Infrastructure Services
* To include Data Mediation; Metadata & Metadata Discovery; Service Orchestration; Service Discovery; People Discovery; Content Discovery; Device Discovery; Middleware; Federated Search
Network Access (All IP & IPv4/IPv6 Capable)
* To include CANES and non-CANES interfaces
Information Delivery
* To include data transport infrastructure in support of Expanded Maritime Interception
System Management Services
Performance, Availability, and Service Level Management
* To include performance, availability, & Service Level Agreement (SLA) monitoring; QoS;
Fault, Problem, Incident, and Service Desk Management
* To include automated handling of system faults and/or failures; help desk management;
Configuration, Change, and Release Management
* To include automatic establishment of system baseline; automatic maintenance of system
Security Management
* To include security incident prevention/reduction; security incident detection; security incident
Capacity Management
* To include monitoring and management of system usage; recording and reporting of system

Table 7. CANES System Capabilities (from PEO C4I 2009)

In addition to providing the capabilities identified in Table 7, as previously mentioned, an OPNAV review identified a number of specific network capability gaps that CANES was to address. Table 8 identifies six specific capability gaps that CANES is required to address (PEO C4I 2009).

Capability Gaps to Be Addressed by CANES	
System Interoperability	Systems unable to fully support interoperability and security for operation in a distributed environment (GIG MA ICD); failure to use open standards and Net-Ready interfaces to permit cross domain flow of information; integration and interoperability of existing and future systems (GIG ES ICD); The operational community needs solutions to support the sharing of information within DoD as well as with interagency, and authorized allied, coalition, and multinational partners as appropriate (Warfighter CONOPS); minimal vertical/ horizontal information exchange and coordination among the National Military Command System (NMCS), Combatant Command (COCOM)/Service/Agency, Intelligence Community (IC), Homeland Security/Homeland Defense, and multi-national components. (Net-Enabled Command Capability (NECC) CDD)
Collaboration	Teams cannot consistently and effectively interact in real time (GIG MA ICD); difficulty finding data or inability to use once found due to a lack of common understanding of what data means (GIG ES ICD); when users can access needed data, they may find the data unusable due to a lack of understanding of what the data means or the structure of the data; lack of relevancy due to time lag (Warfighter CONOPS); current systems do not provide adequate integrated collaborative capabilities to support vertical/horizontal C2 information exchange/coordination among the NECC Community. (NECC CDD)
Information Access	Existing systems focused at the Service level; users are unaware that needed data already exists; publication of and subscription to required information is available only at the local level (GIG MA ICD); information exchange in response to events or requests is not available; rapidly indexed/cataloged, distributed, stored, searchable, and retrievable information is not available; information is not uniformly tagged (GIG ES ICD); Users and producers of information cannot rapidly index, catalog, store, search, and retrieve required information (Warfighter CONOPS); web-based capabilities to access/search, generate, post, or advertise mission-relevant information are not sufficient; insufficient ability to retrieve, broker, translate, aggregate, fuse, or integrate information (NECC CDD)
Cross-Domain Security	Users are unable to access data due to security, technical challenges, or organizational boundaries; information exchange problems with our authorized allied and coalition partners (GIG MA ICD); incapable of cross–domain security supported from a user desktop; inability to rapidly tailor access to GIG ES information and services for Non-DoD users; secure exchange of information between differing security domains is unavailable (GIG Information Assurance (IA) ICD, GIG ES ICD); Operational security considerations have a direct impact on a command's dissemination policy, which will limit access (Warfighter CONOPS); exchange of data of various classifications across multiple security domains (UNCLAS through TS and SCI) via a secure infrastructure is unavailable; lack of broad access to national imagery/intelligence databases and integration of theater-produced intelligence. (GIG IA ICD, NECC CDD)
Information Exchange	Minimal capability to process multiple languages of both spoken language and applications; inability to capture cultural context in which humans function; heavy reliance on text message formats and inability to process multimedia presentations (GIG MA ICD); marginal ability to provide to relevant DoD, non-DoD, authorized allies/coalition partners survival information and updates; lacking ability to associate information or data element security classification levels, releasability, and Special Handling Caveats; mediation of multiple spoken and computer-based languages; advanced information exchange, e.g., web-based messaging (GIG ES ICD); minimal capability to process multiple languages of both spoken language and applications limits the effective presentation of information; this situation is particularly constraining in allied and coalition operations (Warfighter CONOPS); NCES must be compatible with allied users on the Secret Internet Protocol Router Network (SIPRNET) and available to allied users entering the SIPRNET via mechanisms such as Globally Reaching Interactive Fully Functional Information Network (GRIFFIN)
System Responsiveness	Increased demands for data storage capacity, transmission speeds, and information availability; operational fragmentation and segregation of information; data flow across systems and domains; unacceptably slow access to pull or push data even when user has mission priority (GIG MA ICD); information processing is optimized at Service, COI, or local level and does not maximize capacity, decrease redundancy, or increase interoperability (GIG ES ICD); Operational fragmentation and segregation of information by type, classification, command, and mission make it difficult to transport, store, and process essential information (Warfighter CONOPS); does not provide the capability to forward local intelligence and analysis into national databases. (NECC CDD)

Table 8. Capability Gaps Addressed by CANES (from PEO C4I 2009)

CANES was developed to provide the warfighter with the capabilities listed in Table 7 and to address the capability gaps identified in Table 8. Warfighter user requirements are addressed in the CANES CDD as Key Performance Parameters (KPPs) and Key System Attributes (KSAs) that are required to support the system capabilities to be delivered by CANES. KPPs are the system parameters considered most essential to the warfighter and the KSAs are parameters that support developing the optimal engineering solution to deliver the desired capability. As with all DOD acquisition programs, threshold and objective values are established for each KPP and KSA in the CDD.

1. **CANES KPPs**

Key Performance Parameters (KPPs) are those attributes or performance characteristics considered most essential for an effective military capability. The KPPs capture the minimum operational effectiveness and suitability attributes needed to achieve the overall desired capabilities of the related system designed to deliver the capabilities. The CDD states the operational and support related performance attributes of the system being developed to provide the capabilities required by the warfighter. All KPPs contain an initial value that can be verified by testing or other analysis (Joint Chiefs of Staff 2015). Table 9 contains a listing of the CANES KPPs.

As a CFE Network, the SWAN did not have to go through the DOD 5000 Acquisition rigor required of CANES. And, as a result, the argument can be made that the SWAN, and other CFE networks such as the TSCE, were never designed to fully meet warfighter capability requirements in terms of Systems Availability, Material Availability, and the Net-Ready KPP required of all information technology systems. This is an item that must be considered by Navy leadership when considering selecting CFE C4I systems for installation on New Construction ships in the future.

KPP #	Capability	Initial	CCJO Characteristics
1	System Availability	Critical services >= 0.99	Enduring / Persistent; Resilient
		Non-Critical services >= 0.95	
		Critical user access devices >= 0.99	
		Non-Critical user access devices >= 0.85	
2	Material Availability	Critical services >= 0.95	Enduring / Persistent; Resilient
		Non-Critical services >= 0.90	
		Critical user access devices >= 0.95	
		Non-Critical user access devices >= 0.80	
3	Net-Ready KPP	CANES shall fully support execution of Joint critical operational activities identified in the applicable Joint and system integrated architectures and the system must satisfy the technical requirements for transition to Net-Centric military operations to include the following:	Networked; Interoperable; Expeditionary; Adaptable / Tailorable; Enduring / Persistent; Precise; Fast; Resilient; Agile
		1) DISR mandated GIG IT standards and profiles identified in the TV-1	
		2) DISR mandated GIG KIPs identified in the KIP declaration table	
		3) NCOW-RM Enterprise Services	
		4) IA requirements, including availability, integrity, authentication, confidentiality, and non-repudiation, and issuance of an Interim Approval to Operate (IATO) by the Designated Approval Authority (DAA)	
		5) Operationally effective information exchanges and mission critical performance and IA attributes, data correctness, data availability, and consistent data processing specified in the applicable Joint and system integrated architecture views	

Table 9. CANES Key Performance Parameters (KPPs) (from PEO C4I 2009)

To highlight this point further, one major performance problem with the SWAN is its inability to guarantee a minimum level of Quality of Service (QoS) for an array of applications. The fundamental issue is that the SWAN does not have a formal requirement for QoS at the application layer (Riposo 2012). Basically, the SWAN has a high-speed backbone network with edge switches that connect other networks, which have applications loaded on servers. The SWAN does have a QoS requirement for the backbone network. However, there are no QoS specifications for the edge networks, which are not part of the core network (Riposo 2012).

What this means is that for the networks connected to the edge switches, the data service is basically on a first-come, first-served basis. This works fine during periods of low data traffic. However, when there is a requirement to distribute data requiring high bandwidth, such as for video or high resolution imagery, the data packets will start to be dropped by the system. Clearly, this is a major impact to the warfighter.

One of the critical lessons learned from the SWAN design approach is that QoS must extend all the way to the applications loaded on the networks connected to the edge devices. How did this happen? The original specifications for the SWAN were at the ship specification level, which is too high. Since the SWAN was a CFE approach managed by the Electronic Systems Integrator, industry was given the task of applying the requirements to the lower levels, with no process in place for the government to dictate QoS requirements (Riposo 2012). Looking ahead to CANES, QoS is a requirement called for in the CDD that must be satisfied (PEO C4I 2009).

2. CANES KSAs

Key System Attributes (KSAs) are system characteristics that are considered essential to achieving a balanced solution, but not critical enough to be designated a KPP. Like KPPs, KSAs must be measurable, testable, and quantifiable (Joint Chiefs of Staff 2015). Table 10 is a listing of the CANES KSAs.

KSA #	Capability	Description
1	Network Access	Refers to the ability of the end user to interface with the system infrastructure in order to obtain the specified computing resources and services
2	Voice	Refers to the ability to provide users an asynchronous environment to transmit and receive audio signals using Voice over Internet Protocol (VoIP) technology
3	Video	Refers to the ability to support point-to-point and point-to-multi-point Video Teleconferencing (VTC) and video distribution services over the IP network
4	Network Support	Refers to the ability to provide Information Assurance and Multi-Level Security (MLS) services
5	Information Management	Refers to the planning, manipulating, and controlling of information throughout its life-cycle (e.g., creation or collection, processing, dissemination, use, storage, andvdisposition)
6	Core Infrastructure Services	Refers to the software applications and services that are made available and accessible to the end user through the network infrastructure and are shared among multiple end users
7	Systems Management	Refers to the set of system functions (or services) that facilitate the means to monitor, manage, and control CANES and systems dependent on CANES
8	Material Reliability	Refers to a measure of the probability that the system will perform without failure over a specific interval
9	Ownership Cost	Refers to providing a balance to the sustainment solution by ensuring that the Operations and Support (O&S) costs associated with materiel readiness are considered in making decisions
10	Systems Training	Refers to assessing the job tasks, curriculum material, classroom aids, training devices, imulator/stimulators, technical training equipment, and other equipment used to train personnel and selected civilians / contractors to operate, maintain, and employ specific systems across the Information Systems Technician and Electronics Technician Training Continuum

Table 10. CANES Key System Attributes (KSAs) (from PEO C4I 2009)

Section 6.2 of the CANES CDD contains detailed information that defines each KSA in output oriented, measurable, and testable terms. In addition, the CDD lays out development threshold and objective values for each KSA. The basic premise behind the CANES KSAs is that they were used to incentivize the CANES contractor to add additional enhancements and capability during the development phase of CANES in the effort to develop an optimal product that meets the warfighter needs and capabilities.

C. CANES Platform Sets

The CANES acquisition and development strategy is centered on what is known as Platform Sets. A Platform Set (PS) is basically a set of CANES variant designs organized by group. For instance, Platform Set 1, includes the CANES design for a DDG 51 Class Destroyer, which was the first CANES variant to be produced, tested in the lab, and installed onboard a Navy ship. Table 10 below provides a summary of the CANES Platform Sets.

Platform Set 1	Platform Set 2	Platform Set 3	Platform Set 4
DDG – Guided Missile Destroyer	CG – Guided Missile Cruiser CVN – Carrier Vessel Nuclear (Multi-Purpose Nuclear Aircraft) LCC – Landing Ship Control (Amphibious Command Ship) LHA – Landing Helicopter, Amphibious (General Purpose Amphibious Assault Ship) LHD/LHA-7 – Landing Helicopter Dock (Multi-purpose Amphibious Assault Ship) LSD – Landing Ship, Dock MOC – Maritime Operations Center TTE – Technical Training Equipment	BCA – Broadcast Control Authority SSBN – Submersible Ship Ballistic Missile Nuclear SSGN – Submersible Ship Guided Missile Nuclear SSN 21 – Submersible Ship Nuclear (Nuclear-Powered Seawolf Class) SSN 688 – Submersible Ship Nuclear (Nuclear-Powered Los Angeles Class) SSN 774 – Submersible Ship Nuclear (Nuclear-Powered Virginia Class) SUBOPAUTH - Submarine Operating Authority	AS – Submarine Tender JHSV – Joint High Speed Vessel LCS – Littoral Combat Ship LPD – Amphibious Transport Dock LPD-17 – Amphibious Transport Dock

Table 11. CANES Platform Sets (from PEO C4I 2009)

Please note that the LPD CANES variant falls under Platform Set 4, which was under development at the time this research was being conducted. Section E of this chapter will provide an overview of the CANES Systems Engineering Process and how it is being used to develop the LPD CANES variant, the first ship set of Platform Set 4.

D. CANES TECHNICAL BASELINE DEVELOPMENT

As discussed previously in the Capability Need Determination section of this research, the CANES capabilities, KPPs, and KSAs have been established and documented. Looking to the future, the CANES Program intends to offer enhancements to the capabilities currently available and add new capabilities driven by warfighter needs (CANES CDD). The specific capabilities now offered by CANES are identified in the Operational Availability (Ao), Material Availability (MA), and Net Ready KPPs identified in Table 9.

A decomposition of the CANES capabilities, as defined in the CDD, was completed and is published in the CANES Architecture Specification (AS). The goal of the CANES AS is to translate the CANES CDD capabilities and System Views (SV) into an initial set of functional and non-functional requirements such that they can be traced back to the user needs (PEO C4I, 2010). Figure 6 shows the linkage of the CANES capabilities and how they are translated into successive engineering, functional, allocated, and finally the product baseline.

Considering that the CANES CDD defines the capabilities that CANES is required to deliver to the warfighter and that the KPPs establish metrics for determining how well CANES is performing as a system in delivering the defined capabilities, Figure 7 shows how the CDD drives the Architecture Specification (AS), which in turn, translates the user-defined capabilities expressed in the CDD into specific engineering requirements from which a series of CANES system development baselines can be iteratively developed (PEO C4I, 2009).

As the system development process continues from the Functional Baseline through successive engineering iterations, the solution space grows narrower and narrower until an optimal system design is determined. The functional architecture and correlated requirements expressed in the Functional Specification serve as the origin and impetus for the physical design at the Allocated and subsequent baselines.

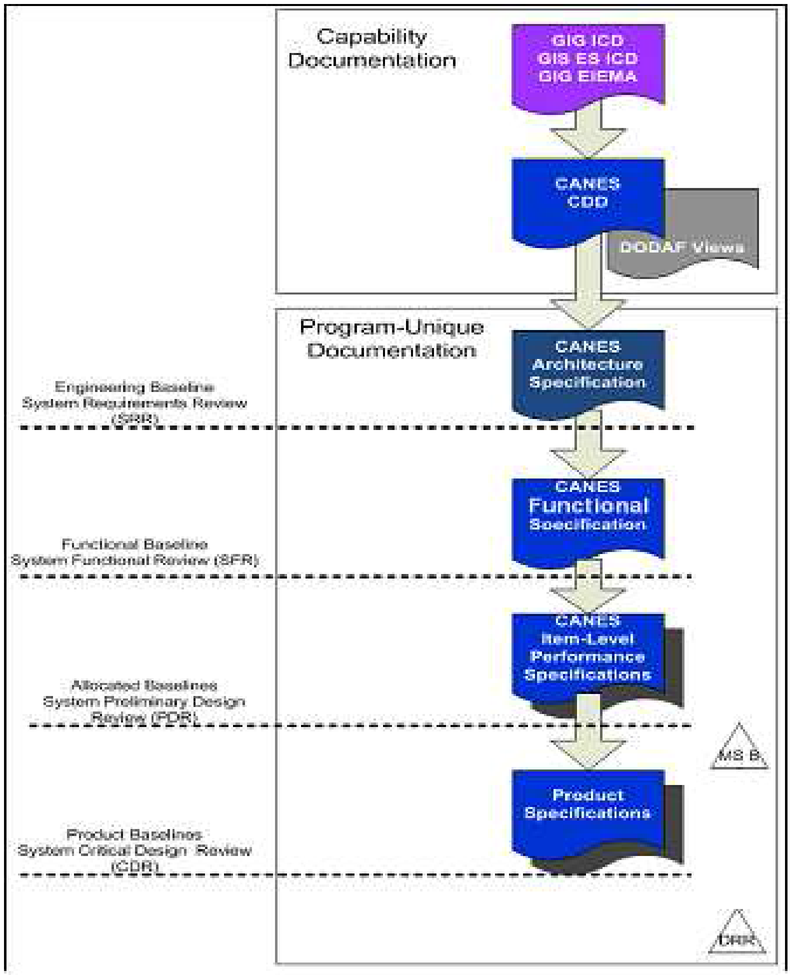

Figure 6. CANES CDD Relationship to Product Specifications and Baselines (from PEO C4I 2009)

E. CANES SYSTEMS ENGINEERING APPROACH

As depicted in Figure 7, the CANES Systems Engineering Team followed the Systems Engineering "V" Model to develop CANES. This model, first formally described by Kevin Forsberg and Harold Mooz, starts with the user needs on the upper left and ends with a user-defined system on the upper right. On the left side, decomposition and definition activities resolve the system architecture, creating details of the design. Integration and verification flows up and to the right, as successively higher levels of subsystems are verified. Verification and validation progresses from the component level to the validation of the entire operational system. At each level of testing, the originating specifications and requirements documents are consulted to ensure that the components, subsystems, and system meet all specifications (Blanchard and Fabrycky 2006)

Using the Systems Engineering “V” Model proved highly effective in translating the warfighter capability requirements laid out in the CANES CDD into an end product that was testable against those requirements. The following sections provide an overview of process.

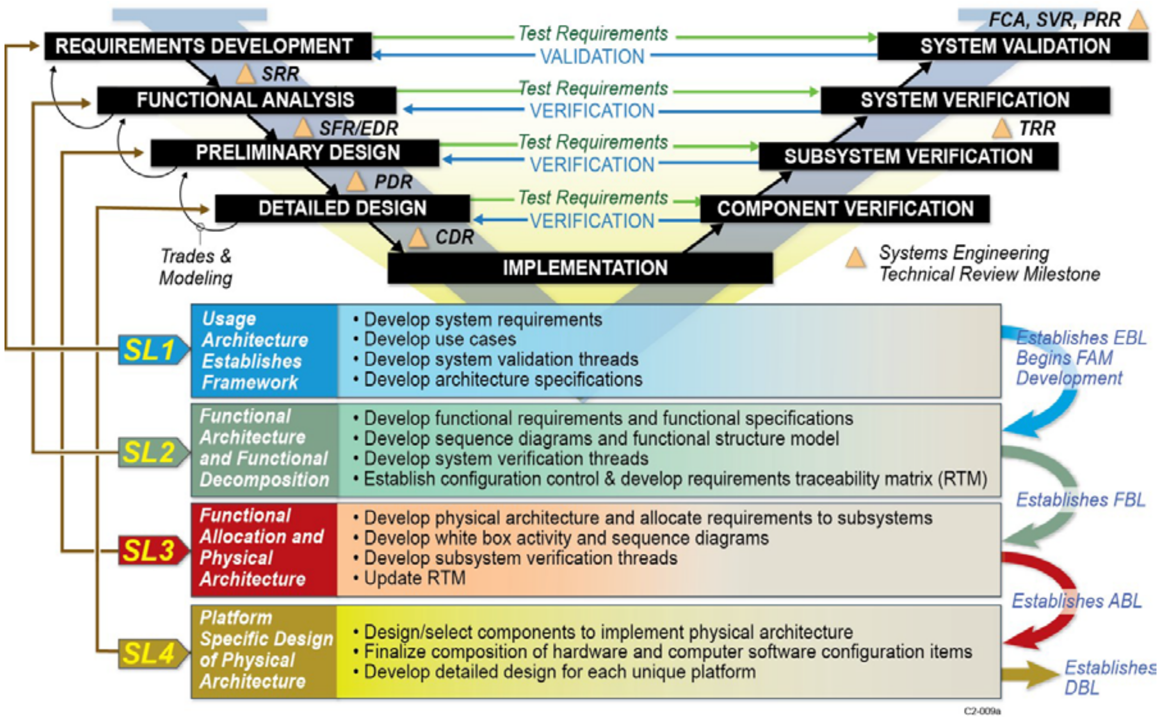

Figure 7. CANES Systems Engineering “V” Model (from PEO C4I 2010)

1. Requirements Development

Requirements Development was the first challenge faced by the CANES SE Team. It was during this phase that the CANES SE Team used information from the CANES CDD, KPPs, KSAs, DODAF Operational Views (OVs), program constraints, and Test & Evaluation Master Plan (TEMP) to develop system requirements, use cases, system validation threads, and architecture specifications (PEO C4I 2010). A Systems Requirements Review (SRR) was conducted and the approved output of the

Requirements Development Phase was a validated CANES Engineering Development Model (EDM). An overview of the Requirements Development phase is depicted in Figure 8.

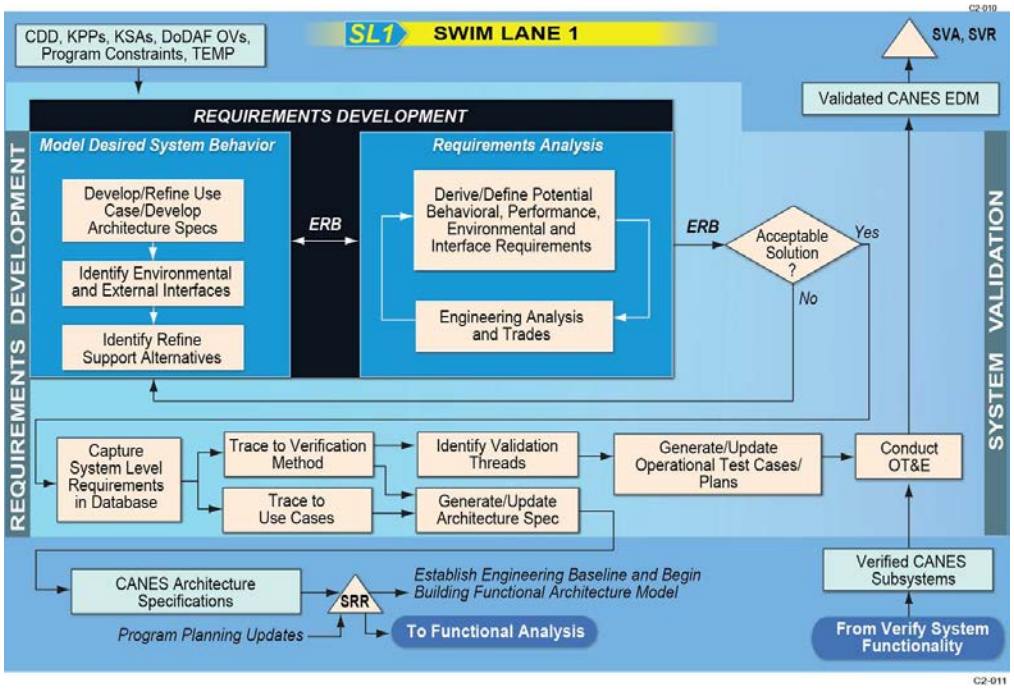

Figure 8. CANES Requirements Development (from PEO C4I 2010)

2. Functional Analysis

The next challenge was to take the Engineering Baseline (EBL) produced during Requirements Development and to conduct Functional Analysis. During this phase the CANES SE Team developed functional requirements, functional specifications, sequence diagrams, a functional structure model, system verification threads, and established Configuration Control of the baseline, and developed a Requirements Traceability Matrix (RTM). A Systems Functional Review (SFR) was conducted and the approved output of the Functional Analysis Phase was a Functional Baseline (FBL) (PEO C4I 2010). An overview of the Functional Analysis phase is depicted in Figure 9.

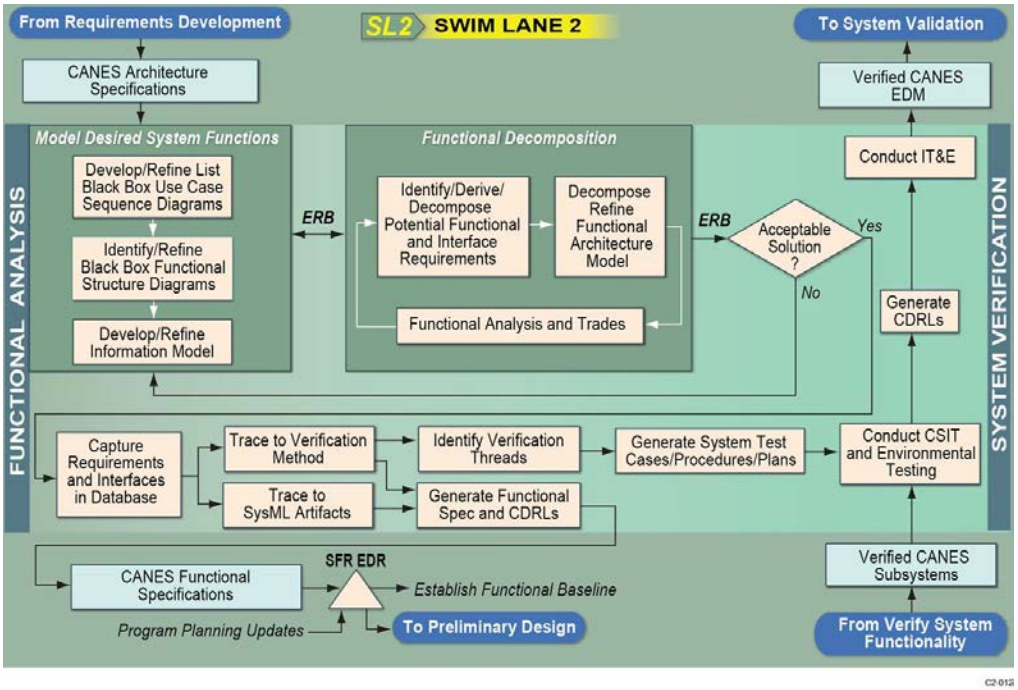

Figure 9. CANES Functional Analysis (from PEO C4I 2010)

3. Preliminary Design

Following Functional Analysis, the CANES SE Team next entered the Preliminary Design Phase of the SE Process. During this phase the CANES SE Team developed the CANES physical architecture, allocated requirements to subsystems, developed sequence diagrams, developed subsystem verification threads, and updated the RTM. A Preliminary Design Review (PDR) was conducted and the approved output of the Preliminary Design Phase was an Allocated Baseline (ABL), which included subsystem specifications for CANES subsystems, such as racks, storage devices, and software packages (PEO C4I 2010). An overview of the Preliminary Design Phase is depicted in Figure 10.

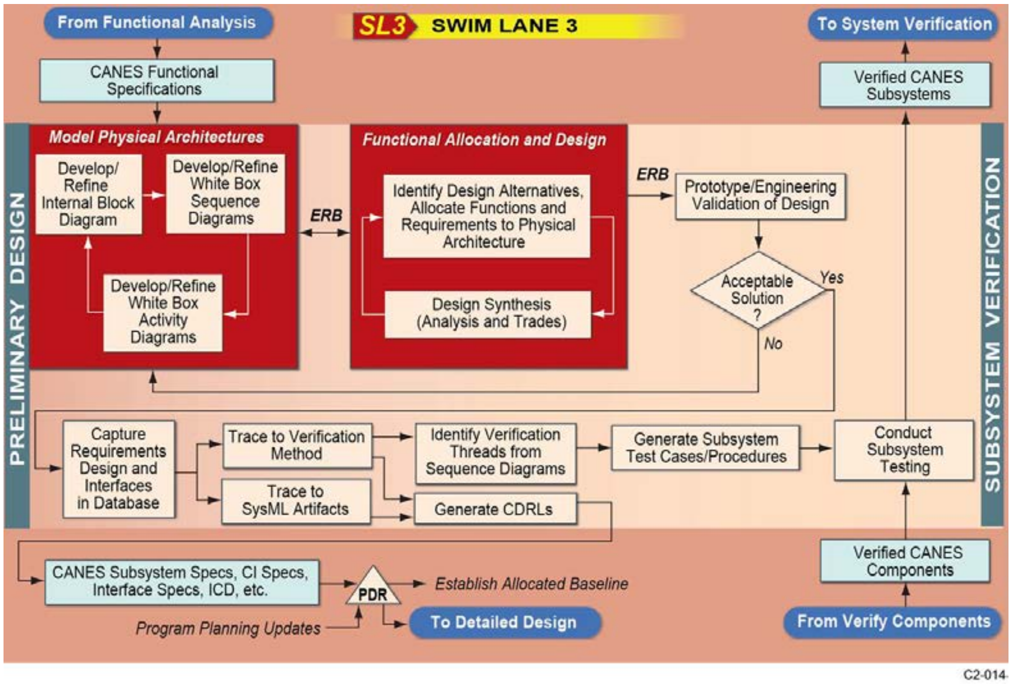

Figure 10. CANES Preliminary Design (from PEO C4I 2010)

4. Detailed Design

Following Preliminary Design, the CANES SE Team next entered the Detailed Design Phase of the SE Process. During detailed design, the CANES SE Team selected components to implement the physical architecture, finalized the composition of hardware and software, and developed a detailed design for each unique Platform Set. A Critical Design Review (CDR) was conducted and the approved output of the Detailed Design Phase was a Design Baseline (DBL), which included component level specifications and detailed design information (PEO C4I 2010). An overview of the Detailed Design Phase is depicted in Figure 11.

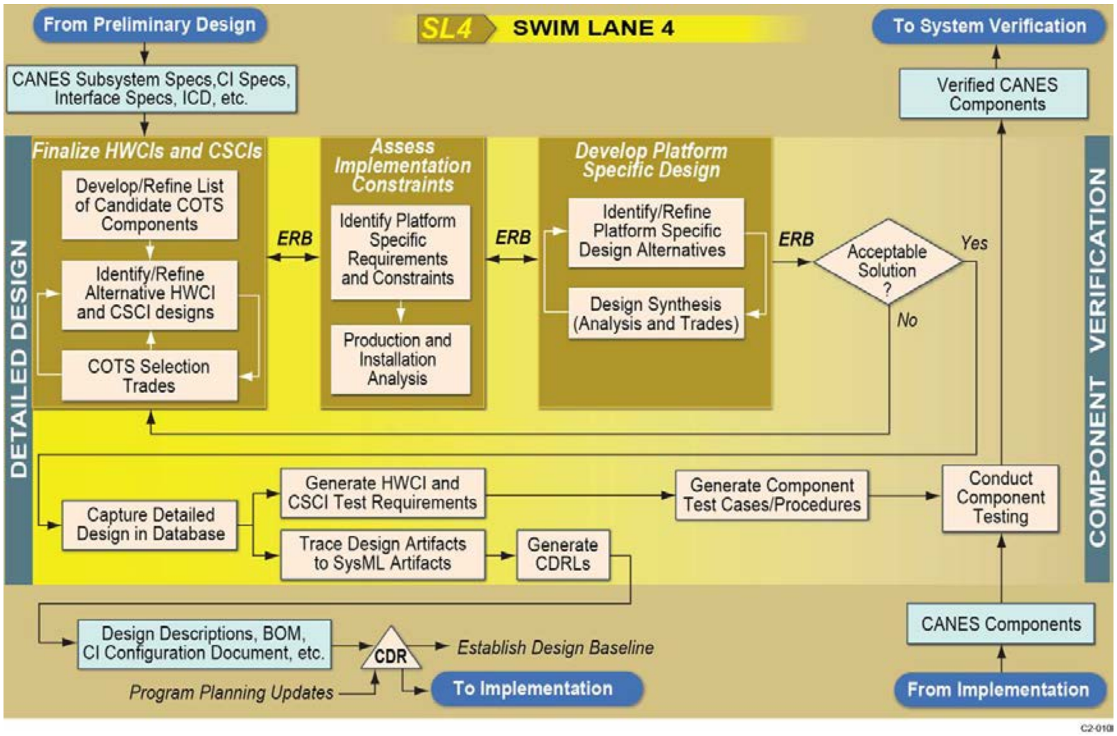

Figure 11. CANES Detailed Design (from PEO C4I 2010)

5. Implementation and Beyond

Following Detailed Design, the CANES SE Team next entered the Implementation Phase of the SE Process. This is the start of the effort to build, test, and integrate the CANES Engineering Development Model (EDM), better known as the "Test Set." In this phase the CANES SE Team went on to establish the framework for completing the remaining phases of the SE Process—Component Verification, Subsystem Verification, and System Validation (PEO C4I 2010). Figure 12 shows the various Contract Data Requirements Lists (CDRLs) that the CANES SE Team used for Implementation.

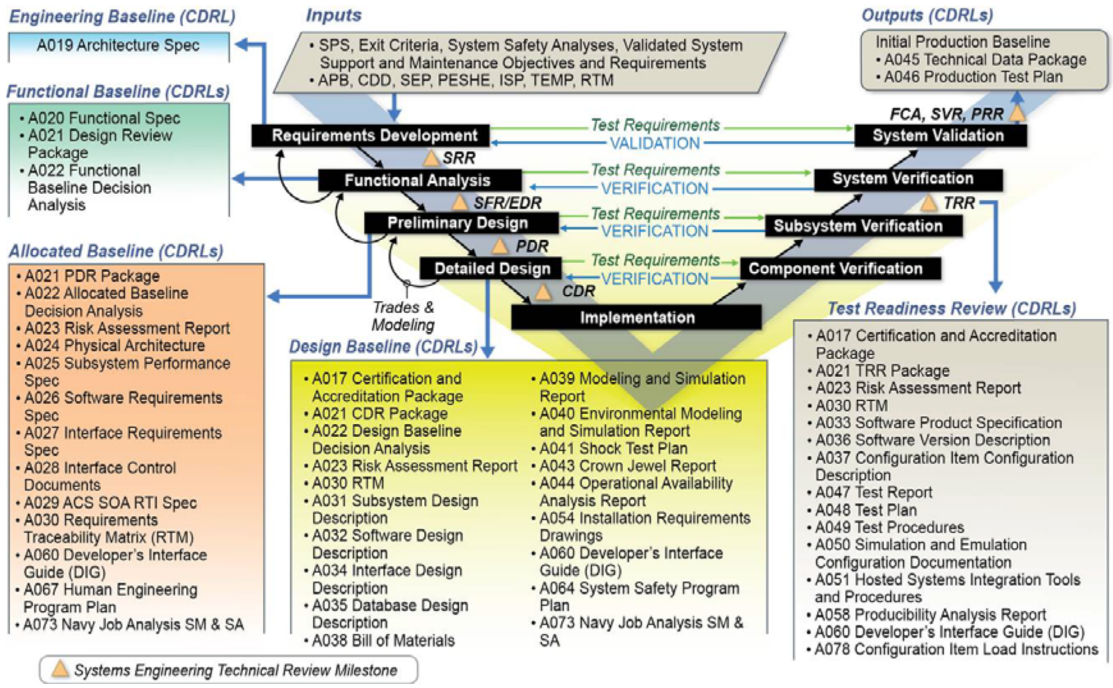

Figure 12. CANES Implementation (from PEO C4I 2010)

With the Implementation Phase completed, the CANES SE Team worked with the Contractor to build an EDM and conducted component, subsystem, and system verification testing. Along each step of the way, testing was completed to ensure that the requirements established during the Design Phase (the left hand side of the SE V) were being met by the system designed. The horizontal lines labeled “Test Requirements” represent the linkage between requirements and verification / validation. Subsystem Integration and Verification testing was done to develop Technical Data Packages (TDPs) for the CANES subsystems. Then, System Verification testing was done to develop a TDP for the CANES system as a whole.

Closing out the SE V, an IOT&E was successfully completed on a CANES system installed on a ship in January 2015. The IOT&E event was used to validate that the system worked properly and satisfied all requirements set forth in the CDD. With a successful IOT&E completed, authority was granted by the Milestone Decision Authority (MDA) for the CANES Program to proceed to the Full Deployment Phase of fielding.

Figure 14 on the following page shows the CANES development cycle from Capability Need to Installation and Sustainment onboard ship.

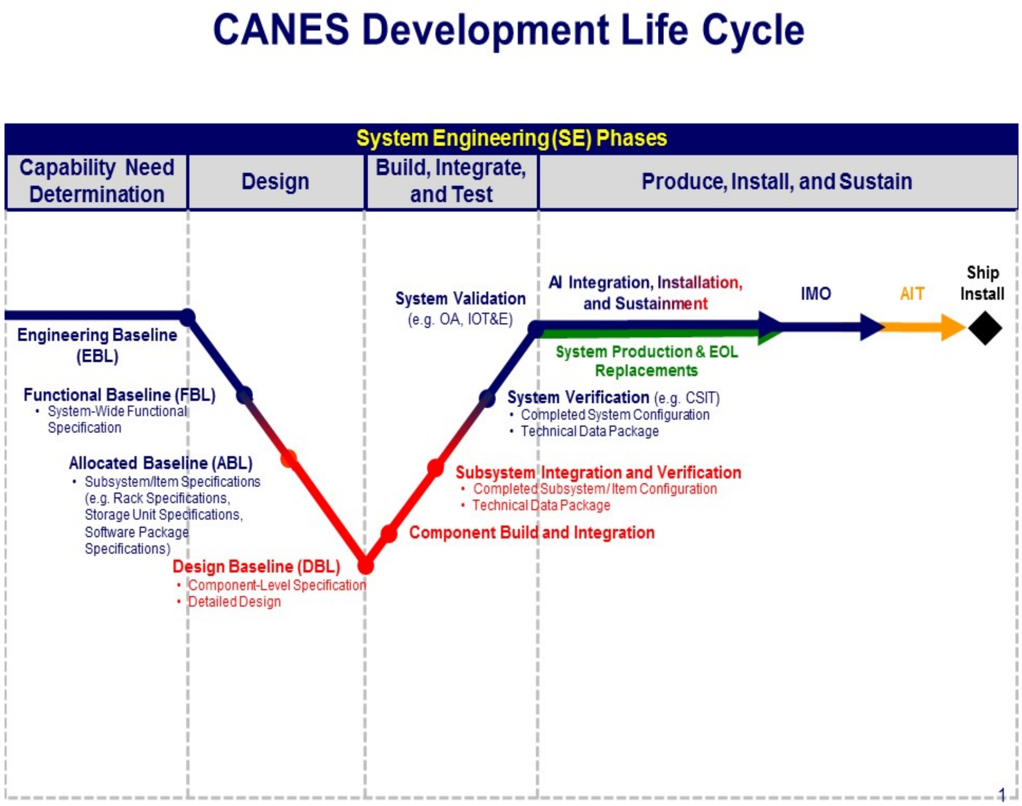

Figure 13. CANES Development Life Cycle (from PEO C4I 2009)

As Figure 13 shows, the ultimate goal of the CANES Program Office effort is to get CANES installed onboard U.S. Navy ships. And, in order to install CANES, five fundamental items are required: (1) CANES hardware, (2) software, (3) Installation Requirements Drawings (IRDs), (4) Ship Installation Drawings (SIDs), and (5) the Configuration Item Control Drawing (CICD). The hardware listing, software listing, and IRDs are products of the SE Process, where the hardware and software is included in the Bill of Materials (BOM) for CANES and the IRD is the CANES design on paper for the given ship variant. The Ship Installation Drawing Package is a set of drawings that describe how to install CANES hardware onboard a ship. The CICD includes detailed instructions on how to load the software on CANES. The objective of the CANES SE

Team is to develop and maintain Configuration Control of the CANES BOM, IRDs, and CICD for each CANES variant design via the Systems Engineering Process.

As of March 2015, CANES has been installed on the following classes of U.S. Navy ships: DDG 51 Class, CG 47 Class, LSD 41/49 Class, CVN 68 Class, CVN 78 Class, LHD 1 Class, and LHA 6 Class. Per Table 11 on page 35, this covers Platform Sets 1 and 2. However, CANES has not been installed on any of the ship classes that fall on Platform Sets 3 or 4 (The LPD 17 Class CANES effort falls under Platform Set 4 and is currently in development). In addition, no New Construction Ship has yet to deliver to the Navy with CANES installed, as all CANES installations have occurred on In Service ships via the Navy Modernization Process during CNO AVAILs. So, in and of itself, the installation of CANES during New Ship Construction presents a unique challenge.

One of the key tenets of the CANES design approach is scalability. Therefore, a significant amount of commonality exists from one ship class CANES design to another. However, each CANES design is tailored to the unique requirements and capability needs of a given ship class. The effort to develop the LPD 17 Class CANES variant builds on the Systems Engineering work previously completed in building the other CANES variants. So, the same SE Process model approach laid out in sections 1–5 of this chapter still applies for the LPD 17 Class CANES development effort.

The biggest challenge facing the CANES SE Team with respect to developing the LPD 17 Class CANES design is ensuring that all core functions previously performed by the C4I Network portion of the SWAN will be captured in the new LPD 17 Class CANES variant design. This is very important because with the LPD 17 CANES effort represents the first time in which a GFE Network on any U.S. Navy ship will replace an existing CFE Network. So, one crucial goal is that when all is said and done, the C4I network capabilities that were in place prior to the CANES install will still be in place (and hopefully enhanced) after the CANES installation is completed.

Keeping in mind that LPDs 17 – 27 all had the SWAN installed inline by the shipbuilder during New Ship Construction, any attempts to install CANES inline on LPD 28 will carry unique Cost, Schedule, and Technical Performance risks. For, if the

Department of the Navy decides to press ahead and install CANES on LPD 28 during New Ship Construction, it would be the first time that the shipbuilder will be installing CANES on an LPD 17 Class ship. The ability of the shipbuilder to install the SWAN on LPDs is firm and stable, for the shipbuilder has a firm design and experience. This is not the case with CANES. So, there is a bit of inherent risk at stake here.

The unique challenge facing the Department of the Navy for LPD 28 is that a Request for Proposal (RFP) supporting the award of the Shipbuilding Contract will be released in October of 2015. And, the RFP must include a Technical Data Package (TDP), which will provide enough detail regarding construction requirements, systems to install, etc., for the shipbuilder to review and provide a bid to build the ship. So, in preparation to release the RFP, a decision has to be made as to whether to install SWAN during New Ship Construction, which the shipbuilder has successfully done in the case with all previous LPDs, or change direction and install CANES inline, which is immature in design and will be new to the shipbuilder. In short, the Navy is facing the decision whether to install an older, legacy shipboard network, which will have to be replaced at great cost after LPD 28 delivers to the Navy, or install the latest shipboard network inline during New Ship Construction.

F. CHAPTER SUMMARY

The Systems Engineering Approach to solving complex problems entails three fundamental steps: (1) define the problem in the form of requirements captured in specifications; (2) creatively synthesize the requirements into design solutions believe to satisfy those requirements, and (3) prove through testing and other methods that the resultant product does in fact satisfy the requirements, thereby, solving the original problem (Grady 1998).

The CANES SE Team used the Systems Engineering Approach to solve the complex problem of designing, testing, and integrated a C4I network for installation onboard U.S. Navy ships. The problem to be solved was defined in the requirements, KPPs, and KSAs, as laid out in the CANES CDD. Then, the CANES SE Team synthesized those requirements into design solutions represented by the EBL, FBL, ABL, and finally, the DBL. And, finally, the CANES SE Team proved that the design developed satisfied the original problem through verification testing on an Engineering Developmental Model (EDM) in the lab and then validated that the original requirements were met by conducting an IOT&E event at sea on a CANES system installed onboard a ship.

There are three widely accepted Systems Engineering Process Models: (1) the Waterfall Model, (2) the Spiral Development Model, and (3) the “V” Development Model (Blanchard and Fabrycky 2006). The CANES Systems Engineering Team chose to use the Systems Engineering V Development Model to design, build, test, and integrate CANES. From the establishment of the Capability Need and well defined requirements, as laid out in the CANES CDD, to the validation of the CANES system installed onboard ship at sea during IOT&E, the SE V Process Model proved highly effective for the CANES Program.

IV. DESIGN BUDGET OVERVIEW

A. INTRODUCTION

In a perfect world, mature and stable Government Furnished Information (GFI) for C4I and information technology systems would be available to support the shipbuilder's detailed design and construction effort at the shipbuilding contract award date. However, as previously discussed in the Introduction, C4I and information technology equipment is forever rapidly changing due to Moore's Law. For this reason, obsolescence risk is an ever-present concern in the world of shipbuilding.

This point is well communicated in a study conducted by the Rand Corporation (2011) titled *Are Ships Different*? The Rand study reports on page 15 that "For ships, MS B typically occurs before the detail design and construction contract is awarded, but after the preliminary and critical design reviews." This is relevant when one considers the fact that MS C is when C4I Acquisition Programs normally have good, stable design information (i.e., final Interface Control Drawings). So, the New Construction Ship MS B dates rarely align well with the MS C dates for rapidly evolving C4I systems, such as CANES. It is in the case where the Ship Construction milestone dates are misaligned with the individual system acquisition milestone dates where trade space negotiation with the shipbuilder is crucial. Within the context of the DOD 5000 Acquisition Framework, a better way of merging the Shipbuilding construction GFI requirement milestones with GFI the maturity of individual C4I systems is needed.

B. THE CASE FOR DESIGN BUDGET

The dilemma facing the Department of the Navy as to whether to install the SWAN on LPD 28 during New Ship Construction or break up the SWAN and install CANES for the C4I network portion of SWAN, speaks to the crucial issue of balancing the early shipbuilder GFI needs to support New Ship Construction vs individual system GFI maturity. This is not a new problem. This is an issue facing every New Construction where the construction timeline exceeds five years. In each case, a brand new ship is delivered to the Navy with obsolete information technology equipment installed, requiring costly upgrades during the first Post Delivery Modernization AVAIL window. These costly upgrades are a source of wasted taxpayer dollars and resources.

Figure 14 below shows how delaying the final GFI Required Delivery Date (RDD) decreases information technology obsolescence risk at ship delivery. For LPD 28, it should be noted that the RFP release date for LPD 28 is October 2015, which is just a few months after the initial Installation Requirements Drawings (IRDs) will be ready for the LPD 17 Class variant CANES design. However, the time between issuing the Detailed, Design, and Construction (DD&C) Contract to support New Ship Construction and ship delivery is about six years for LPD 28. This great period of time is the primary source of obsolescence risk for LPD 28, as the ship that will not be delivered to the Navy until 2022. In the effort to mitigate information technology obsolescence risk to the shipboard network, a new Shipbuilding Acquisition Strategy must be implemented for LPD 28.

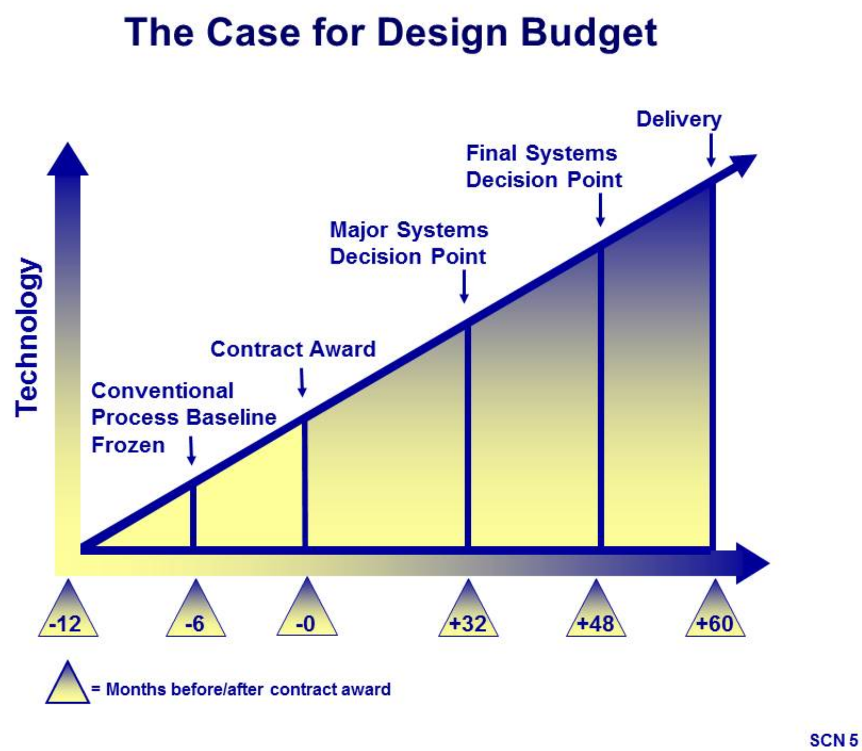

Figure 14. The Case for Design Budget (from PEO C4I 2010)

C. DESIGN BUDGET DEFINED

From actual language proposed by PEO C4I for inclusion in the Ship Construction Contract for LHD 8, “Design Budget” is defined as the process by which the Government schedules the release of final ship compartment outfitting specifications after target cost, target profit, ceiling price, and ship delivery schedule have been established. The primary goal of Design Budget is to provide the U.S. Navy with the most technologically advanced C4I systems available, without incurring a significant increase in shipbuilding costs due to design changes or construction schedule impacts.

The Design Budget approach characterizes the C4I system in terms of parametric values rather than specific system details, such as exact nomenclature, size, weight, power. This allows for continued C4I system maturity and for change to be accommodated within the parametric budgets or boundaries established without impacting the shipbuilder. In essence, Design Budget allows advanced information technology C4I systems such as CANES to evolve transparently to the shipbuilder. From a briefing given in 2010 by PEO C4I to PEO Carriers proposing that the Design Budget Approach be adopted for inclusion in the CVN 79 Ship Construction Contract, the core tenets of Design Budget include the following:

- Establishment of Size, Weight, and Power (SWaP) envelopes
- Phased delivery of GFI to the shipbuilder
- Use of a Production Integration Facility (PIF) to test and integrate the system and prepare it for delivery to shipbuilder
- “Just in Time” delivery of GFE to the shipbuilder
- Use of the Pre-Planned Product Improvement (P3I) Process to allow for smart C4I Modernization
- Inclusion of language in the Shipbuilding Contract and other Ship Program Acquisition Documents that support the Design Budget Approach

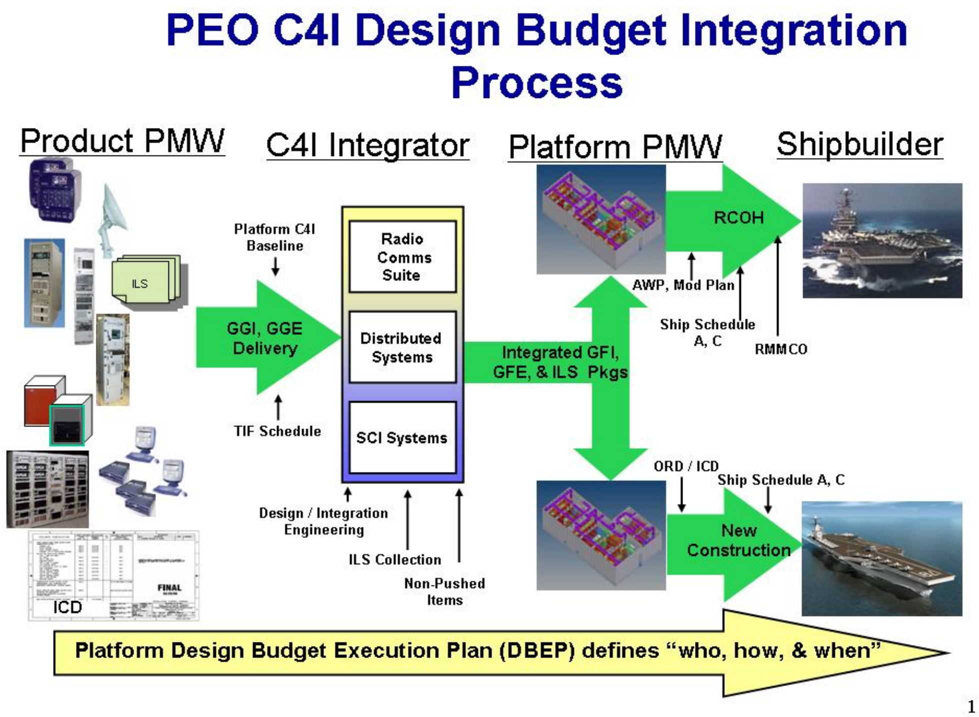

Figure 15. High Level Overview of Design Budget Process (from PEO C4I 2010)

Figure 15 is a depiction of the Design Budget Process for the Radio Communications Suite for Aircraft Carriers (CVN 71 RCOH and CVN 77 New Construction). The Product PMW, such as the CANES Acquisition Program Office, provides the equipment information and hardware to the C4I Integrator. The C4I Integrator integrates the system and provides the GFI and GFE to the shipbuilder, so that the shipbuilder can install the systems at the shipyard.

D. DESIGN BUDGET CORE TENETS

1. Establishment of SWaP Envelopes

The Design Budget approach involves establishing design envelopes for C4I equipment, which include design parameters that cannot be exceeded, such as Size, Weight, and Power (SWaP) and Heating, Ventilation, and Air Conditioning (HVAC). Establishing the SWaP and HVAC design envelopes enables the shipbuilder to proceed with the design and development of the shipboard spaces containing the C4I network equipment (and associated the associated infrastructure, such as wireways, power, fan rooms, and inter-compartment cabling) without requiring the actual C4I equipment to be physically present at the ship and ready for installation. This approach provides much greater flexibility by allowing the installation of the latest hardware versions, preventing the need for costly equipment rip-outs after ship delivery.

2. Phased Delivery of GFI

As mentioned above, the establishment of design envelopes is a core tenet of the Design Budget Approach. However, in order for the design envelopes to work, phased GFI must be provided to the shipbuilder to support the shipbuilder’s effort to design, procure, and plan for the installation of long lead shipboard infrastructure items, such as power generation and distribution equipment. Phased GFI products include the following:

- Space arrangements
- Parametric data
- Cable routing diagrams
- Power diagrams
- Equipment outline and mounting diagrams

3. Use of a Production Integration Facility (PIF)

Every effort should be made to allow for the testing and integration of C4I equipment, including network equipment racks, servers, in a land based Production Integration Facility (PIF) prior to GFE Delivery to the shipbuilder. The primary objective of the PIF is to fully test and integrate the C4I equipment in an environment that reflects the representative operational configuration onboard the designated ship. In the case of CANES, this includes the pre-loading of all software prior to GFE Delivery to the shipbuilder.

The goal with the use of the PIF is not to duplicate product line testing, but to ensure that the C4I capability to be delivered to the shipbuilder will be fully interoperable and ready for installation. Land-based testing at the PIF brings a disciplined Systems

Engineering approach to the shipboard platform level test and integration process. This approach results in a fully tested and certified system ready for installation.

4. Just in Time Delivery of GFE to the shipbuilder

The Schedule A dictates when GFE is required for delivery to the shipbuilder. Typically, the dates listed in the Schedule A are driven by compartment availability based on the Ship Construction schedule. The impact of locking in the Schedule A dates early will be that delivery of C4I equipment will be required years in advance of actual light off. This is the primary driver of information technology obsolescence risk.

One core tenet of Design Budget is to deliver as late as possible in the effort to avoid information technology obsolescence. One method of satisfying the shipbuilder’s need to land racks inside shipboard compartments prior to space closeout is to deliver empty racks so that the shipbuilder can land the racks in the respective space and install them on the rack foundations. This mitigates the issue of having to cut an access into a space to facilitate bringing large equipment racks later. The ‘Just in Time’ delivery of GFE aspect of this tenet occurs when the electronic equipment to populate the racks is delivered a few months prior to Electronic Light Off (ELO). Another benefit of Just in Time GFE Delivery is that the sensitive C4I equipment is protected from exposure to the harsh shipyard environment, thus preserving the life of the equipment.

5. Use of Pre-Planned Product Improvement (P3I) Process

The P3I Process enables concurrent development of a system and its subsystem components. P3I allows for flexibility in procurement when the system life cycle and Shipbuilding Project schedules do not align well. In cases where the C4I system is at great risk of being obsolete, it may make more sense to have the shipbuilder install only the required infrastructure during New Ship Construction and to defer the actual system install until after ship delivery. Use of the P3I Process in this manner can avoid both the risk of IT system obsolescence and the need for costly equipment rip-outs post ship delivery.

6. Inclusion of Design Budget Language in the Ship Construction Contract

The final tenet of Design Budget is that actual language be included in the Detailed Design and Construction (DD&C) Contract for the ship, along with the Ship Acquisition Program documents, such as the Acquisition Strategy (AS). This is the most important of all tenets of Design Budget. For, if the language is not included in the Shipbuilding Contract or the Acquisition documents, there will be no means to execute Design Budget during the New Ship Construction effort.

E. BENEFITS OF DESIGN BUDGET

One example that shows how big a difference that the Design Budget Approach can make during New Ship Construction is the LHD 1 (WASP) Class of Force Level Amphibious Assault Ships. C4I systems were delivered and installed on LHD 1 – 7 in the conventional manner. However, the Design Budget Approach was implemented on USS MAKIN ISLAND (LHD 8). In a PEO C4I briefing given to PEO Ships by the LHD 8 Integration Platform Manager (IPM) in October of 2010, it was reported that the implementation of Design Budget resulted in a 90% reduction in C4I related Engineering Change Proposals (ECPs) and an estimated cost savings of approximately $22.6M. Here are some of the specific challenges that PEO C4I faced during New Ship Construction on LHD 7 regarding C4I systems:

- C4I baseline design frozen at Shipbuilding Contract Award
- C4I equipment delivered fully populated and too early in the Shipbuilding construction timeline
- C4I equipment integration and testing first occurred onboard ship and just prior to Builder's Trials
- GFI was required very early, forcing the delivery of obsolete C4I equipment
- 25 ECPs were submitted regarding C4I equipment design changes

After implementing the Design Budget Approach on LHD 8, the contrast with LHD 7 was dramatic. Here are a few highlights from the LHD 8 New Ship Construction effort that showcase the impact of the Design Budget Approach:

- Only three ECPs were submitted regarding C4I equipment design changes
- C4I baseline freeze date was pushed one year to the right of Contract Award
- Unpopulated C4I equipment racks were delivered to support Ship Construction
- Just in Time delivery of GFE and empty racks were populated later in the ship construction timeline
- All C4I equipment was fully tested and integrated at a land-based test site prior to GFE delivery to the shipbuilder
- GFI was delivered to the shipbuilder in a phased manner

Clearly, implementation of the Design Budget Approach had a great impact on USS MAKIN ISLAND (LHD 8). This effort saved the taxpayers a significant amount of money and preserved time and equipment resources for the Department of the Navy. The benefits of the Design Budget Approach include the following:

- Significant cost avoidance for the Department of the Navy and the shipbuilder
- Change can be better accommodated as C4I systems evolve
- Risk exposure can be minimized
- Reduced total number of Schedule A line items
- Reduced storage time for C4I equipment at the shipyard
- Reduced exposure of sensitive C4I equipment to industrial environment
- Reduced number of potential Engineering Change Orders (ECOs) and Engineering Change Proposals (ECPs) at the shipbuilder
- Later technology insertion, decreasing risk of obsolescence
- Smaller scope tech refresh required during first Post Delivery AVAIL

The Design Budget Approach affords the Government more flexibility for technology insertion so that ***the right C4I system can be delivered and installed at the right time!***

F. CHAPTER SUMMARY

The Design Budget Approach aligns with the Acquisition Strategy of C4I systems. This is especially true of shipboard network systems, such as CANES. Design Budget pushes the delivery of detailed design information to the right, allowing for the C4I systems to continue to mature, independent of New Ship Construction. The final design GFI is delivered later in the process to support the integration of the latest in technology in meeting the shipbuilder's construction schedule.

Use of the Design Budget Approach affords the government more flexibility for technology insertion on New Construction platforms and a means to avoid information technology equipment obsolescence. The flexibility for technology insertion and obsolescence avoidance is ever important in today's budget constrained environment. Design Budget is a process that when implemented during New Ship Construction projects, has the power to save significant amounts of money, while allowing the shipbuilders to deliver New Construction ships with the latest and greatest in C4I technology capabilities.

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VI. CONCLUSION

A. INTRODUCTION

The Shipboard Wide Area Network (SWAN) was designed and built by Raytheon and installed on the first 11 ships of the LPD 17 Class. As one of the first major Commercially Furnished Equipment (CFE) shipboard networks installed on a New Construction Ship, it was envisioned to be a holistic shipboard network, integrating everything from UNCLAS and Secret C4I network capabilities to Hull, Mechanical, and Machinery (HM&E) network capabilities. However, the SWAN was limited in performance and brought with it mounting sustainment costs to PEO Ships, the Program Office responsible to pay for life cycle sustainment.

As a result of a substantial projected sustainment cost growth for the SWAN, on 04Mar11, the R3B tasked OPNAV N2/N6 and OPNAV N85 (now N95), the LPD 17 Ship Resource Sponsor, to conduct a study on the LPD 17 Class Shipboard Network architecture and to provide a recommendation for the future. On 06Apr11, PEO Ships and PEO C4I formed a joint study team and engaged to research the LPD 17 Class SWAN and to provide a recommendation for the future.

The final recommendation of the SWAN Study was that the C4I network portion of the SWAN be replaced with CANES and that the HM&E portion of SWAN be segregated and become a POR network to be managed by NAVSEA. The study team's recommendation was accepted by the Navy Leadership and approved for implementation via the Navy Modernization Process. The focus of this research was to consider the viability of installing CANES during New Ship Construction on LPD 28, the final ship of the LPD 17 Class, as opposed to the SWAN.

B. SUMMARY OF KEY FINDINGS

1. SWAN sustainment is cost prohibitive in the long run.

A review of the LPD 17 Class SWAN Sustainment Study revealed that the cost to sustain the SWAN across the FY13– 17 FYDP was $99M. On average, that is about $2.5M per hull to sustain only one shipboard system over a four year period of time.

Considering the fact that the U.S. Navy has 275 active ships (www.navy.mil) and the LPD 17 Class will have at most 10 ships by the end of FY17, this was a significant portion of the PEO Ships budget and of great concern to Department of the Navy leadership. Growing concern over SWAN sustainment costs was amplified, when the increasing threat of cyber security vulnerabilities and the unique training requirements tailored to the SWAN was taken into account. Ultimately, OPNAV and ASN (RDA) decided that the status quo was no longer tenable and approved a plan to replace the C4I network portion of SWAN with CANES, the GFE POR shipboard network solution.

2. Replacing the C4I Network portion of SWAN with CANES is the best alternative.

The LPD 17 Network Study team analyzed nine potential COAs, which were eventually down-selected to three: (1) SWAN Enclave Hardware Expansion (COA A); (2) CANES Federated with NAVSEA POR Solution for HM&E (COA B); and (3) CANES Federated with NSWC CD POR Solution for HM&E (COA C). After conducting an extensive analysis of engineering feasibility, cost, and risk, the study team recommended to leadership in December 2011 that COA B be adopted. In January of 2012, OPNAV accepted the recommendation and made the decision to fund the effort to federate the SWAN and replace the C4I Network portion of SWAN with CANES. This decision made in 2012 has been validated, as sustainment cost for SWAN continue to escalate and cyber vulnerabilities for the older SWAN Network increase. With CANES successfully completing the Limited Deployment Fielding Phase of the Program, the Navy is already starting to realize increased C4I network capabilities, greater protection from cyber vulnerabilities, and greatly improved shipboard network performance.

3. The SWAN did not have a formal QoS requirement for applications.

A major performance flaw for the SWAN was its inability to guarantee a minimum level of service for applications loaded on the servers tied to the network. As explained in Chapter III in the CANES KPP discussion, Quality of Service (QoS) is a measure of the ability of a system or process to deliver a service. Research revealed that when the SWAN was being designed at Raytheon, consideration was never given to have a formal QoS requirement implemented at the application layer. In short, the SWAN was designed with a high-speed backbone with edge switches that connect to the backbone.

However, since there was no QoS specification for the edge devices, the edge devices worked on a first-come, first-served basis. This design flaw impacted the QoS of applications during high periods of network traffic on the SWAN. The critical lesson learned from the SWAN is that QoS specifications must always extend to the application layer.

4. CANES has a QoS requirement at the application layer.

The CANES CDD lays out a clear set of KPPs, KSAs, and the Net-Ready KPP. And, included in the KPPs is a requirement under Systems Management to monitor QoS at the application layer. This enhanced feature of CANES to deliver QoS at the application layer is an item that positively impacts the readiness of the warfighter, increasing shipboard readiness.

5. The CANES Systems Engineering V Model was highly effective.

The CANES design, development, integration, and testing effort followed the Systems Engineering V Model. Starting with a clear Capability Need from the warfighter, and stable requirements, as set forth in the CANES CDD, the CANES SE Team methodically worked down the left side of the SE V, decomposing the requirements into a detailed design on paper. Then, the SE Team methodically worked up the right side of the SE V, using the Engineering Development Model built by the contractor to for verification testing of the established requirements in the lab, and an actual CANES system installed onboard ship to complete validation testing during an IOT&E event.

6. GFE networks go through more Acquisition Rigor than CFE networks.

An item that this research has revealed is that the level of acquisition rigor that GFE systems must go through, as mandated by DODI 5000, far exceeds any level of review that CFE systems must go through. As was the case with the LPD 17 Class Ships, the shipbuilder was under contract to deliver the ship to Navy. And, the Electronic Systems Integrator was on contract to design and integrate the SWAN into the ship during New Construction. So, only the ship Top Level Requirements were being closely monitored by the Government WRT DOD 5000 Acquisition requirements, which the CFE SWAN network did not have to satisfy. With the proliferation of commercial-off-the-shelf (COTS) hardware and software in use on Navy ships, assurance of satisfaction of warfighter requirements and design specifications is an item of growing concern.

7. Design Budget is a proven process for avoiding obsolescence risk.

The Design Budget process has been proven effective as a means of avoiding C4I system obsolescence risk and saving money during New Ship Construction. The example given in Chapter 4, which compared the LHD 7 construction effort vs. the LHD 8, shows the dramatic impact that implementing Design Budget can have on New Ship Construction. The Design Budget Process ensures that the Navy is provided with the most up to date C4I equipment suite at ship delivery, which at the same time accommodating the shipbuilder's need for GFI and GFE to support Ship Construction.

C. RECOMMENDATIONS

1. Install CANES on LPD 28 using the Design Budget Approach

Based on the results of this research, it is highly recommended that PEO Ships make the decision to install CANES on LPD 28 during New Ship Construction. Though the decision will impact the shipbuilder, the long term benefits gained will far outweigh any short term costs. Implementation of the Design Budget Approach will help to mitigate obsolescence risk and minimize impacts to the shipbuilder. The decision to install CANES in line during New Ship Construction on LPD 28, along with implementation of the Design Budget Approach, will ensure that LPD 28 will deliver to the Navy in 2022 with the latest and greatest in C4I network capabilities installed.

2. Mandate GFE POR C4I solutions on all New Construction Ships

It is also recommended that the Department of the Navy mandate that all new construction shipbuilding programs make every effort to include GFE POR C4I systems, including shipboard networks, in each ship baseline, as opposed to CFE systems. As previously discussed, the inclusion of CFE networks introduces growing sustainment costs that the Navy must pay. Mandating that GFE POR C4I solutions be installed leverages existing Integrated Logistical Support (ILS) resources, such as spare parts, training assets.

3. Incorporate Design Budget on all New Construction Ship efforts

It is clear that the Design Budget Approach saves money and is a proven way of avoiding obsolescence risk for C4I and IT based systems. It is highly recommended that all Ship Acquisition Program Management (SHAPM) offices include the core tenets of Design Budget in Ship Acquisition Strategies and supporting Design Budget language in the actual Ship Construction Contract when awarded.

4. Review the level of Acquisition Rigor applied to CFE hardware

Based on the revelation that the SWAN CFE network did not require QoS at the application layer, it is also recommended that the Department of the Navy conduct a thorough review regarding the policies for acquiring all CFE systems. It is recommended that a review of guidelines be established for procuring CFE systems and that a requirement be levied that clear performance specifications be established if CFE systems are to be required, when there is no GFE system available. At a minimum, CFE systems should be held to the same standard as an equivalent GFE system. Otherwise, the direct cost comparison of GFE vs CFE holds no value.

D. OPPORTUNITIES FOR FOLLOW ON RESEARCH

Building a New Construction Ship is a complex project spanning multiple years. Effectively planning for the design, procurement, delivery, test, integration, and installation of constantly evolving C4I systems makes this challenge even greater. During the course of this research effort, a number of areas for follow on research were identified. The top five areas for follow on research includes:

- Use of CFE Networks to meet warfighter KPP requirements
- Analysis of the cost to sustain the TSCE Network on LCS
- Analysis of the cost to sustain the TSCE Network on DDG 1000
- Level of oversight applied on Defense Contractor use of CFE
- Total Life Cycle Cost implications for CFE

Based on the review of the SWAN Sustainment Study, further research involving the Total Ship Computing Environment (TSCE), which is a CFE network much like the SWAN, is warranted. In addition, further research is needed about the level of acquisition rigor and oversight applied by the Government to CFE systems.

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